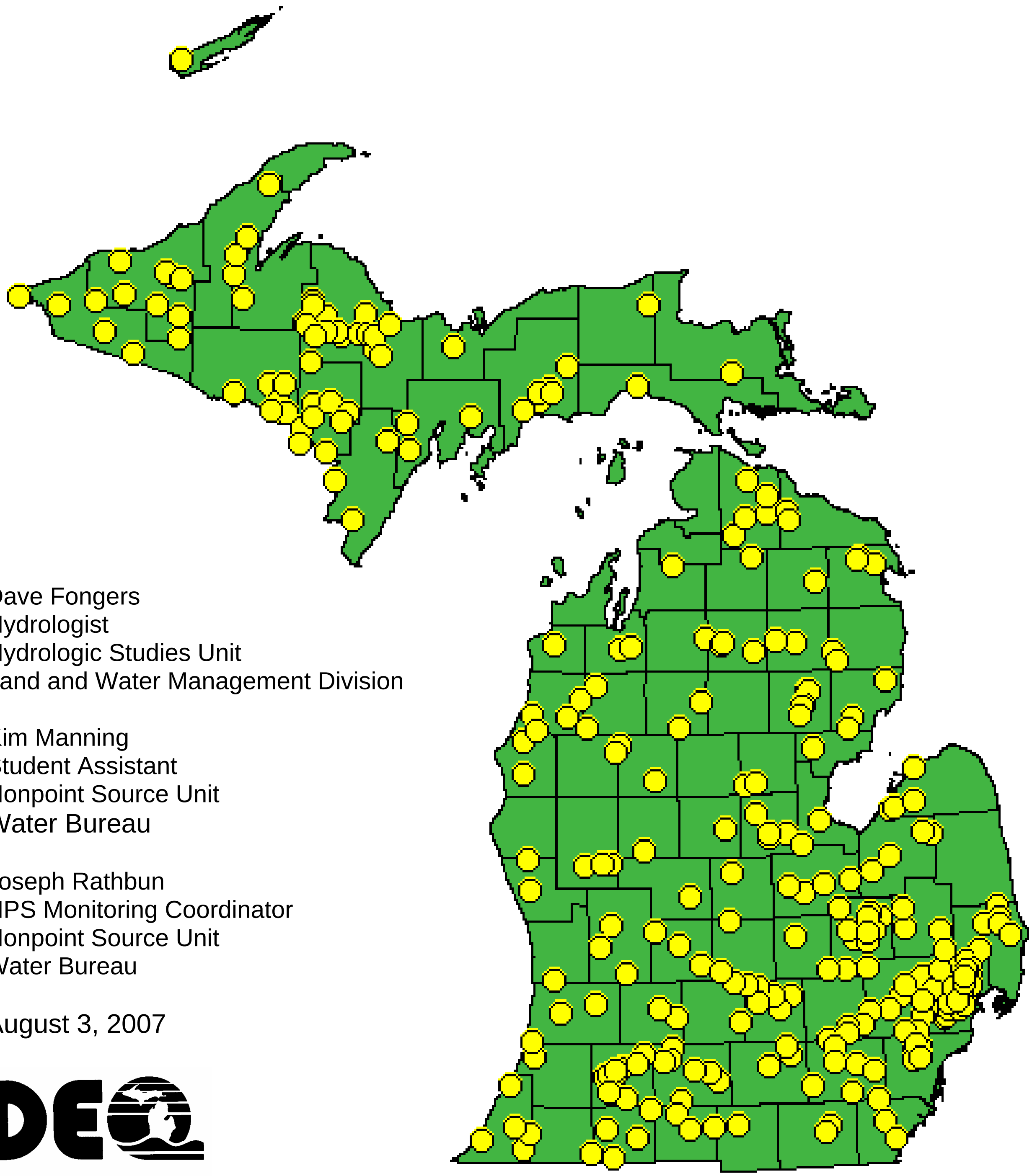
Application of the Richards-Baker Flashiness Index to Gaged Michigan Rivers and Streams



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The cover depicts the United States Geological Survey (USGS) gages analyzed using the Richards-Baker Flashiness Index method.

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Summary

Stream flashiness is the stream flow response to storms. Streams that rise and fall quickly are considered flashier than those that maintain a steadier flow. An increase in flashiness, often due to changing land use, is a common cause of stream channel instability. The Richards-Baker Flashiness Index (R-B Index) uses data from U.S. Geological Survey (USGS) gaging stations to quantify the frequency and rapidity of short term changes in stream flow. MDEQ's Nonpoint Source (NPS) program staff calculated R-B Index values and assessed trends for 279 USGS gages in Michigan that had at least five years of data through the end of water year 2004. The analysis of few added or revised gages include flow data through the end of water year 2005.

It is anticipated that the NPS program grant recipients will incorporate this information in their stream stability assessments and watershed management plans, and also find it useful as an aid to Best Management Practices (BMPs) selection and design. The NPS program may also use the information to guide future grant goals. Michigan's Stream Team (www.michigan.gov/streamteam) expects to use the analysis to guide site selection for development of statewide stream morphology regional reference curves as well as for other purposes. The information should also be useful to those interpreting other data, such as watershed development trends, stream bank erosion rates, or biological survey data.

The yearly-averaged R-B Index values for Michigan watersheds range from 0.006 to 1.009. Fluctuations over time are apparent in a stream's R-B Index values. Some fluctuations in the R-B Index values are expected from year to year simply because of natural weather variations. Longer term trends result from hydrologic alterations within the watershed. We identified trends at gages in operation during the past 25 years that should be influencing the streams' morphology today.

An increase in flashiness, due to higher peak flows or more frequent bankfull flows, may result in measurable changes to the channel shape – width, depth, sinuosity, and slope. These changes occur by erosion. Reducing excessive erosion is a common NPS project objective. A frequent dilemma in selecting and siting NPS BMPs is assessing the scale of the stream channel stability problem versus the scale of the problem's cause. The R-B Index is one tool for diagnosing the scale of a particular stream channel problem.

This report is intended to describe the flashiness analysis methodology and results. It does not attempt to fully explain changes in R-B Index values at specific sites. Further analysis of a specific site or sites within a watershed would be more efficiently and practically performed by local watershed groups and other stakeholders who can often apply watershed-specific and other local information to the interpretation.

The R-B Index values and trends apply only to the stream in the vicinity of the gage. Conditions throughout the watershed may vary. For example, flashy flows in a stream above the gage may be masked by the combined flows of other streams at the gage. Similarly, streams that are increasingly flashy at one gaged location may become stable downstream due to attenuation of flashy flows by tributary flows downstream of the gage.

Introduction

The term flashiness reflects the frequency and rapidity of short term changes in stream flow (Baker et al, 2004). A stream described as flashy responds to rainfall by rising and falling quickly, as shown in Figure 1. Conversely, a stream that is not flashy would rise and fall less for an equivalent rainfall and would typically derive more of its overall flow from groundwater.

One approach to quantifying flashiness was proposed by Baker et al (2004). The method measures the path length of flow oscillations for data from gaged streams. Longer paths correlate with flashier streams, while more constant flows have shorter path lengths. Values for the R-B Index could theoretically range from zero to two. It would have a value of zero if the stream flow were absolutely constant. Its value increases as the path length, and flashiness, increase. An example of R-B Index Values for two Michigan streams with similar drainage areas is shown in Figure 2. The Au Sable River and Lower River Rouge gaged drainage areas are 97 and 84 square miles, respectively. For water year 1991, both gages recorded similar total flows; 900 and 790 billion cubic feet for the Au Sable and Lower Rouge respectively. Despite similar drainage areas and total discharges, the Lower Rouge River exhibited much flashier flows than the Au Sable River, with R-B Index values of 0.56 and 0.05 respectively. This is presumably due primarily to three factors: vegetation, soils, and imperviousness. The Au Sable watershed has more vegetation and sandier, more permeable soils. The Lower Rouge watershed has more impervious surface cover.

One complication in interpreting R-B Index values is the normal change in stream flashiness with changing watershed size. Specifically, smaller watersheds naturally tend to have flashier flows. There is a natural tendency for flashiness to decrease as the drainage area increases because varied timing of tributary flows helps attenuate main channel peak flows, and because soils and land uses tend to become more varied as the watershed size increases. This is reflected in the Baker et al (2004) results, as summarized in Figure 3, which shows that maximum R-B Index values decrease as watershed size increases.

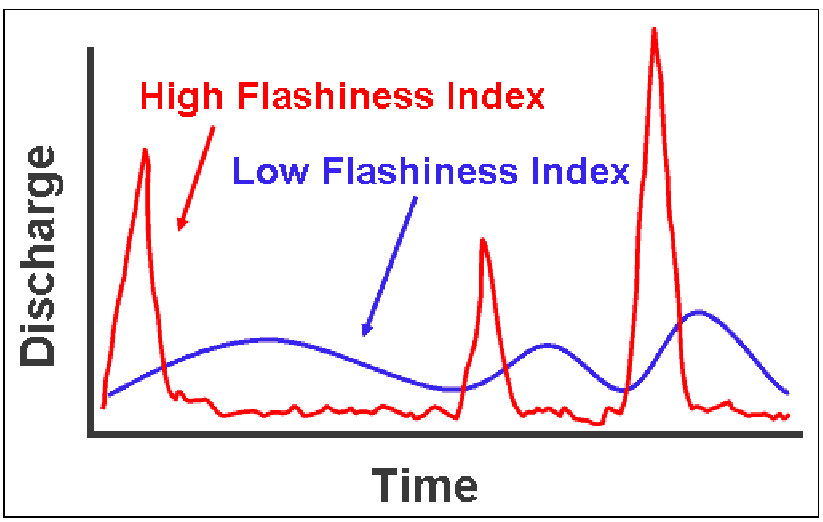

Figure 1 – Example Hydrographs

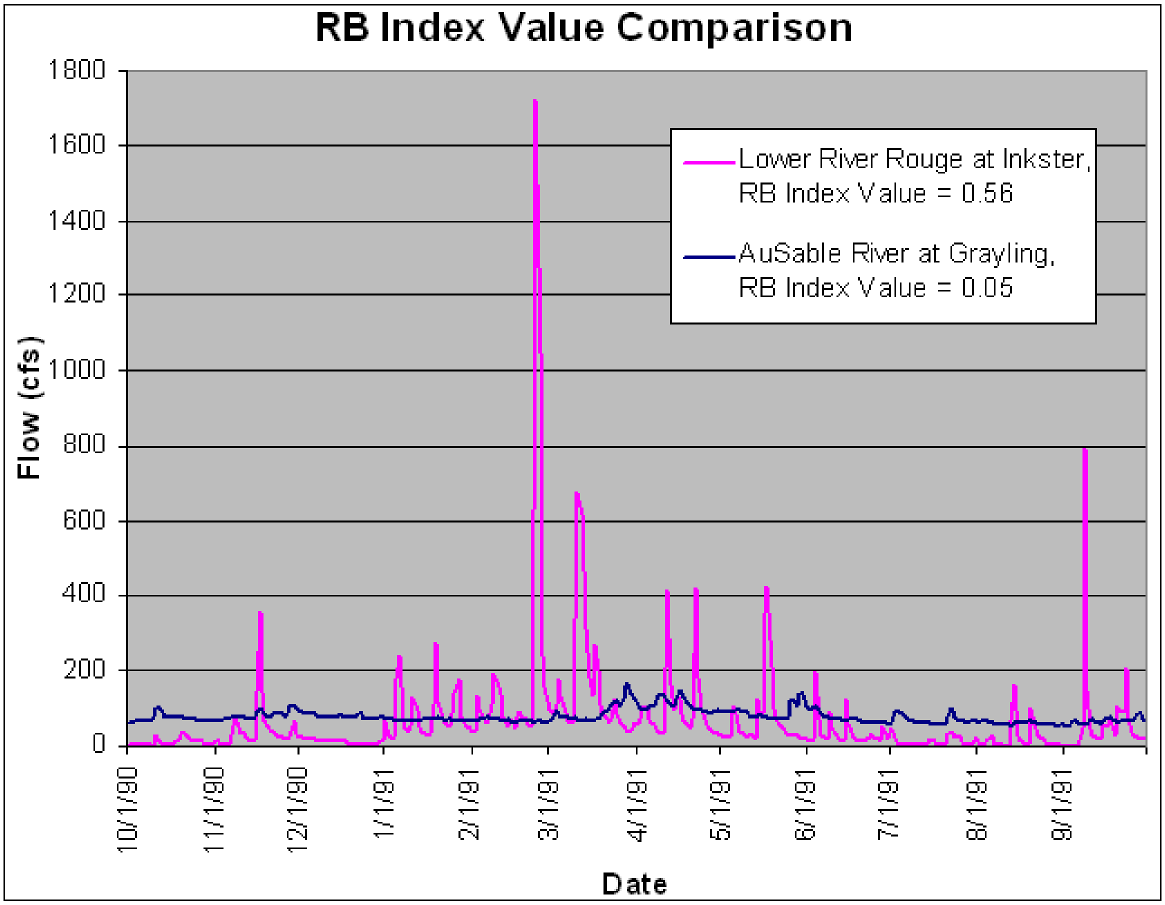

Figure 2 – Hydrographs for Two Michigan Streams

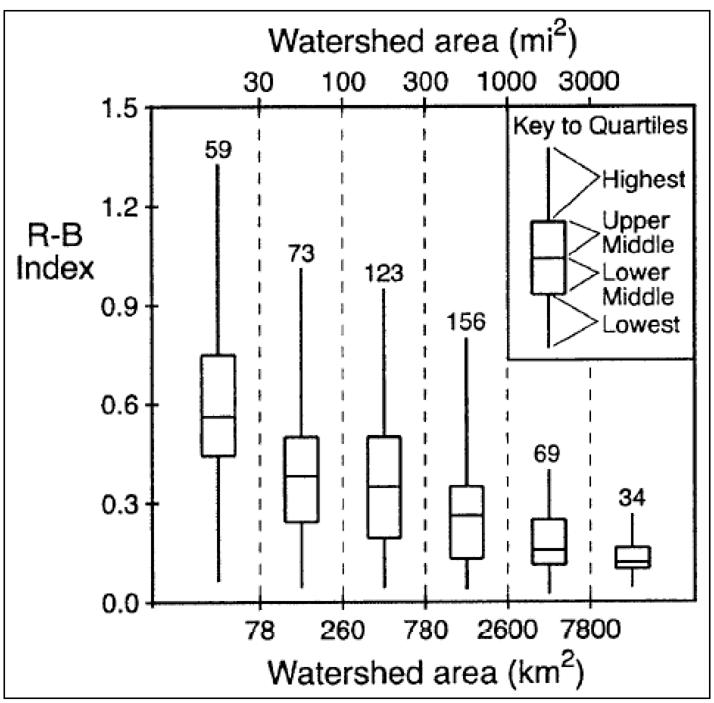

Figure 3 – Summary of the Richards-Baker Data for 515 Gages in Six Midwestern States, including Michigan

Flashiness Analysis of Michigan Watersheds

Overview

R-B Index Value Analysis

This flashiness analysis for Michigan watersheds used average daily flow data from 279 USGS gages. The only selection criterion was that each gage had at least five years of daily data (P. Richards, personal communication, 2005). At the time of our analysis, data was available through the end of water year 2004, which was September 30, 2004. A few gages were added or revised that include flow data through the end of water year 2005.

We did not limit the age of the data, preferring that watershed groups and other users of the results draw their own conclusions with regard to the validity and usefulness of the results, particularly with regard to discontinued gages, for their watershed. Of the 279 gages, 141 have been discontinued. Sixty-nine of the gages included in this report were discontinued over 25 years ago. Flashiness rankings for these gages may not reflect current conditions.

Occasionally, a gage is moved and assigned a new number. If the gages are considered equivalent, the discontinued gage's flow record is included in the new gage's record. Only the newer gage, with the complete record, is included in this analysis. These gages are noted in Appendix A.

The R-B Index values are calculated essentially by summing the absolute values of daily flow differences and dividing by the sum of the daily flows for one year. More detail can be obtained from the journal article by Baker et al (2004).

Flashiness Trend Analysis

Fluctuations over time are apparent in a stream's R-B Index values. Figure 4 illustrates two examples. Some fluctuations in the R-B Index values are expected from year to year simply because of natural weather variations. Longer term trends result from hydrologic alterations, such as a change in land use or removal or change in operation of a dam. An increase in flashiness, due to higher peak flows or more frequent bankfull flows, can result in changes to the channel shape: width, depth, sinuosity, and slope. This is especially true for stream channels that are steep and composed of noncohesive materials (Rhoads et al, 1991). Changes in stream channel shape, in turn, can have significant impacts on aquatic organism populations (Richards et al, 1997; Van Steeter et al, 1998). Because a stream can take 50 years or more to adapt to flow changes (Article 19 in Schueler, 2000), we restricted the trend analysis to gages in operation during the past 25 years. Statistically significant trends in the R-B Index values are identified for 71 of the 210 gages in operation during the past 25 years.

The trend analysis performed for this report includes linear regression analysis of the R-B Index values to identify statistically significant increasing or decreasing trends. Gages discontinued before 1980 were not used in this analysis so that the trends provide a comparative reference of the present condition of Michigan's streams. Isolated data separated by large time gaps, serially correlated data, and data with heterogeneous variance were excluded from this analysis. The linear trend lines shown in Appendix A do not guarantee a linear relationship between flashiness and time for those streams, nor can they be used to predict future flashiness trends for those streams. The goal was to objectively identify flashiness trends influencing each stream's morphology today.

Visual examination of the data plots for each gage indicates that some gages have experienced trend changes. A statistical technique, termed cusum, was then applied to the data, and then the first derivative of the five-year moving average cusum data was plotted. Extremes in the first derivative plots were used to identify possible trend breaks. Where a possible trend change was identified, an additional regression analysis was performed on the gage's more recent R-B Index values. This technique is further explained in Appendix D. If a statistically significant change occurred, only the more recent data were used for the trend analysis and to calculate the average R-B Index values shown in Appendices A and B. The 51 gages that have identified increasing or decreasing trends are summarized in Table 2.

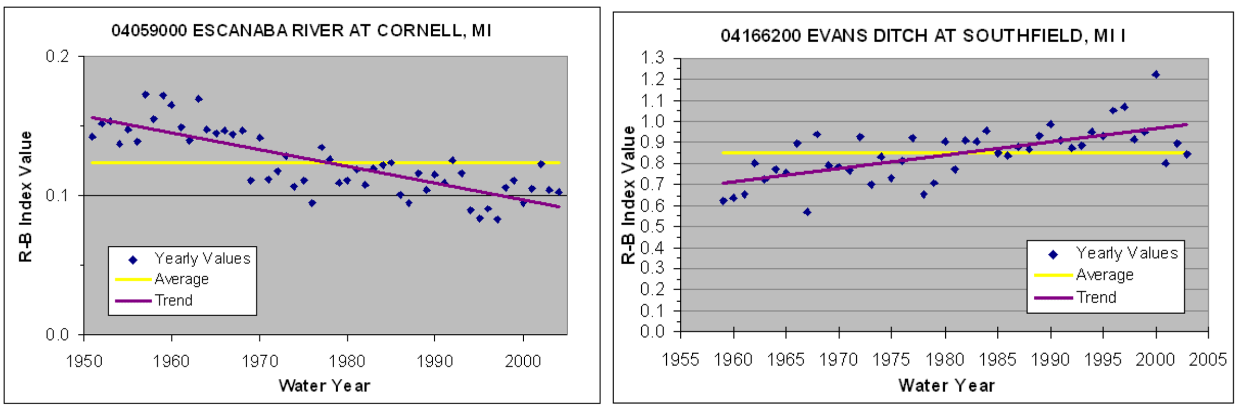

Figure 4 – Examples of Changing Stream Flashiness over Time

Application to NPS BMP Selection

An increase in flashiness, due to higher or more frequent flows, results in changes to the channel shape: width, depth, sinuosity, and slope. These changes occur by erosion. Reducing excessive erosion is a component of many NPS projects. A frequent dilemma in selecting and siting NPS BMPs is assessing the scale of the stream channel stability problem versus the scale of the problem's cause. A bank erosion problem with a local, small-scale cause (e.g., cattle access) can be addressed by a local BMP (e.g., fencing), while a bank erosion problem with a large-scale cause (e.g., a watershed-wide increase in impervious area) can only be addressed with a similarly large-scale solution (e.g., regional stormwater management practices).

The R-B Index is one tool for diagnosing the scale of a particular stream channel problem. If the R-B Index values are steady over time, channel erosion problems in the vicinity of the USGS gage may have local causes that can be addressed with a local BMP. Conversely, if the R-B Index trend indicates that flashiness is increasing over time, channel erosion problems in the vicinity of the gage station may have large-scale causes and will require a large-scale solution. Note that "in the vicinity of the gage" is not well defined. Streams that are increasingly flashy at one location may become stable downstream due to attenuation of flashy flows by tributary flows downstream of the gage. Similarly, flashy flows in a stream above the gage may be masked by the combined flows of other streams at the gage.

Results

General

The MDEQ's NPS program calculated R-B Index values and assessed trends for 279 USGS gages in Michigan that had at least 5 years of data. Graphs of the yearly R-B Index values, averages, and trends for each gage are provided in Appendix A. Appendix B provides more detailed tabular information for each gage site. Appendix C is a map of Michigan's major watersheds that are referenced in these results.

R-B Index Value Results

The R-B Index values for Michigan watersheds range from 0.006 to 1.009, as shown in Table 1. For comparison, the R-B Index values for the Richards-Baker six-state study of 515 midwestern gages ranged from 0.030 to 1.323. The Richards-Baker six-state study used data from 1975 through 2001.

Results of the R-B flashiness analysis for the 279 USGS gages are summarized in Figures 5 through 8 and detailed in the Appendices. Figure 5 is similar to Figure 3, which summarizes the six-state Richards-Baker data. The 3,000-square mile drainage area break point used in that study was omitted in this study because only five gaged Michigan streams exceeded that size.

Figure 6 illustrates the proportion of available gages used for this analysis. Figure 7 illustrates the gage status and the watersheds of the gages used.

Figure 8 illustrates the quartile rankings. Most of the flashiest steams are in the southeastern portion of the Lower Peninsula or the western end of the Upper Peninsula. This is likely a combination of developed land uses and heavier soils. The cluster of less flashy streams in the northern portion of the Lower Peninsula is likely the result of extensive natural land uses and sandy soils. In itself, a high or low ranking is not necessarily good or bad. The rankings may be used to identify areas where methods to reduce flashiness can be employed, or to identify areas where extra effort is warranted to protect our most sensitive and exceptional streams. This is discussed further in the Flashiness Changes and Hydrologic Alterations, Land Use section on page 17.

Table 1 – Summary of R-B Flashiness Analysis Statistics

MDEQ analysis for Michigan	**Drainage Area (sq. miles)**					
	0-30	**30-100**	**100-300**	**300-1000**	**1000+**	
Number of gages	41	73	70	61	34	
Mean	0.365	0.227	0.141	0.136	0.106	
Median	0.314	0.162	0.107	0.116	0.100	
Minimum	0.006	0.043	0.026	0.035	0.046	
25%	0.156	0.101	0.077	0.081	0.074	
50%	0.314	0.162	0.107	0.116	0.100	
75%	0.497	0.325	0.172	0.153	0.122	
Maximum	0.848	1.009	0.433	0.376	0.228	
Richards-Baker analysis for Six Midwestern States	**Drainage Area (sq. miles)**					
	0-30	**30-100**	**100-300**	**300-1000**	**1000-3000**	**3000+**
Number of gages	59	73	123	156	70	34
Mean	0.584	0.414	0.372	0.266	0.179	0.141
Median	0.565	0.382	0.324	0.173	0.161	0.123
Minimum	0.069	0.048	0.049	0.038	0.030	0.046
25%	0.451	0.245	0.199	0.139	0.114	0.105
50%	0.565	0.382	0.354	0.263	0.161	0.123
75%	0.744	0.504	0.499	0.354	0.249	0.166
Maximum	1.323	1.009	0.954	0.801	0.401	0.267

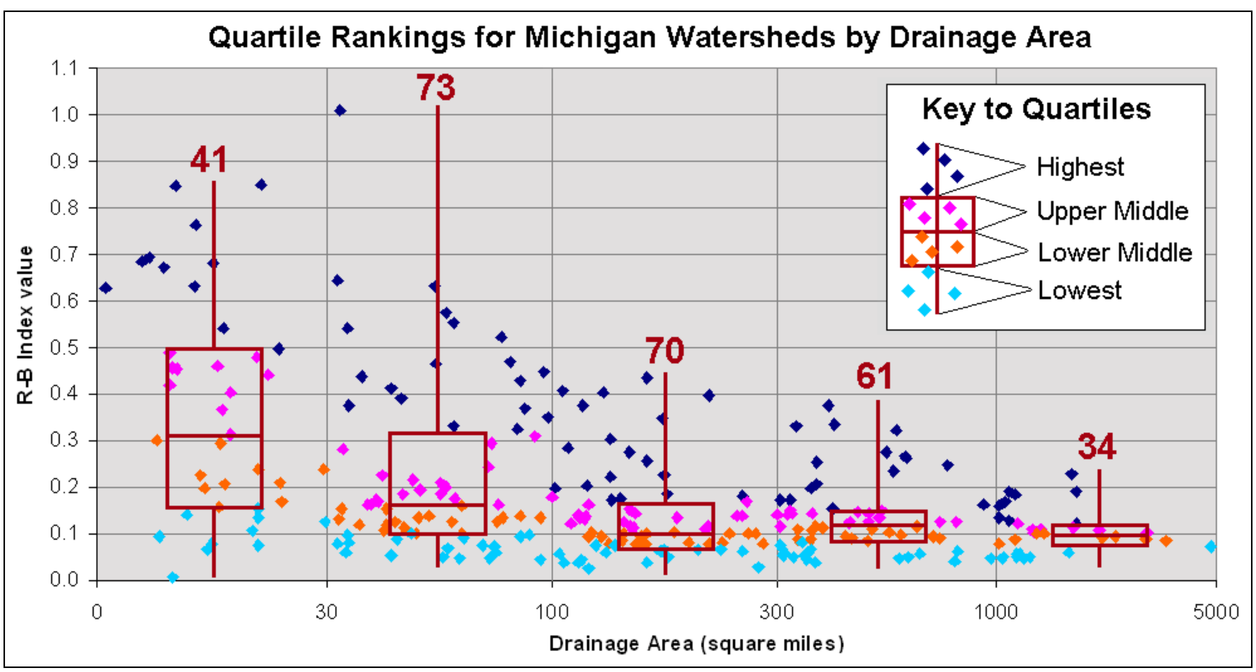

Figure 5 – Summary of Michigan R-B Index values

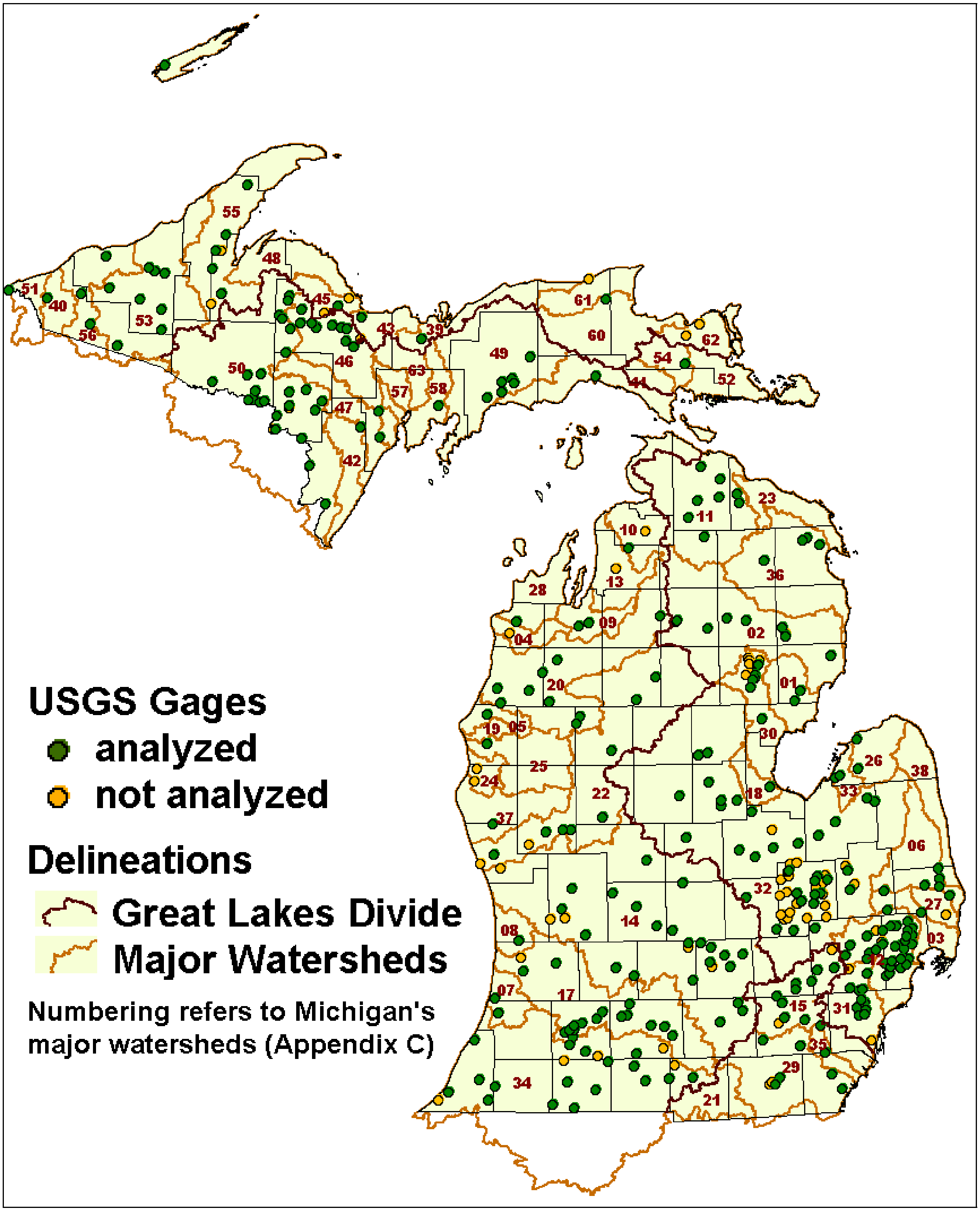

Figure 6 – USGS Gages for Michigan Watersheds

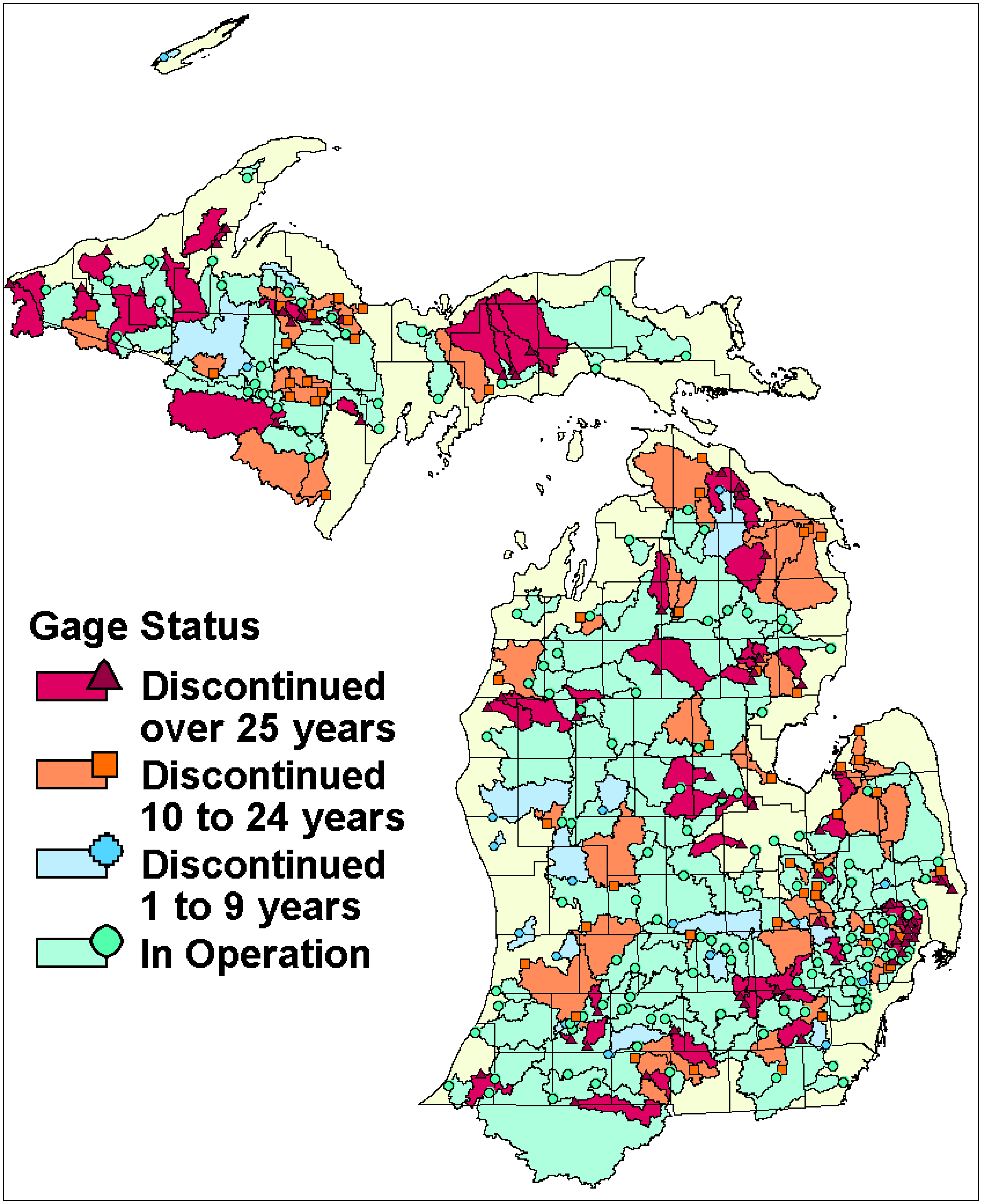

Figure 7 – USGS Gage Status for Michigan Watersheds

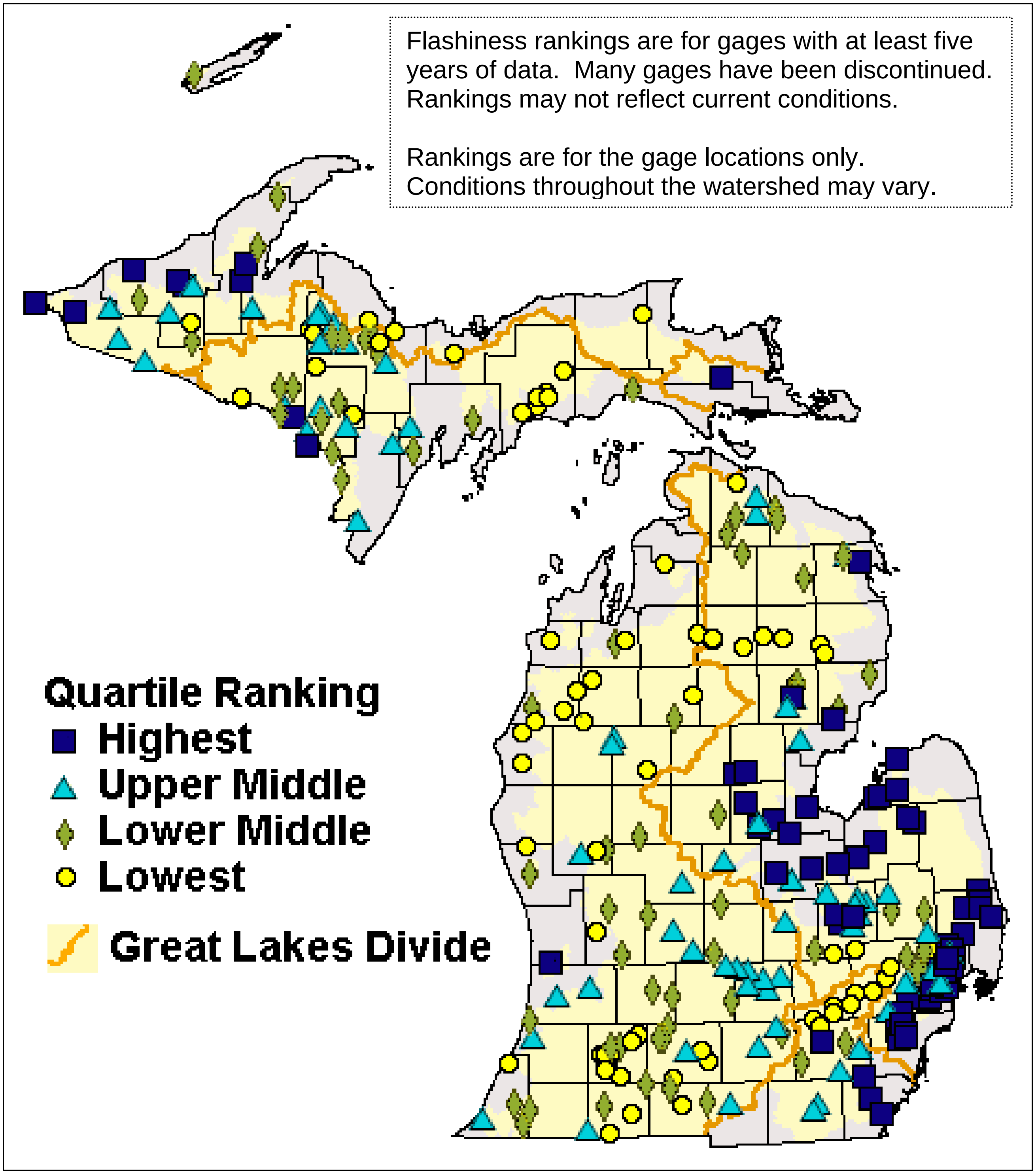

Figure 8 – Quartile Ranking

Flashiness Trend Results

Although a stream can take 50 years or more to adapt to flow changes (article 19 in Schueler, 2000), the trend analysis is restricted to gages in operation during the past 25 years. The identified trends, which may span part or all of the gage record, should therefore be influencing each stream's morphology today. The results of the trend analysis are shown in Figures 9 and 10 and Table 2 and detailed in the Appendices. Statistically significant trends in the R-B Index values are identified for 71 of the 210 gages in operation during the past 25 years. Thirty of the gages have decreasing trends. Forty-one of the gages have increasing trends.

The trends were based in part on visual examination of each gage's data, with linear regression used to objectively verify statistical significance. This does not guarantee that there is a linear relationship between flashiness and time for those streams. The physical processes causing the changes are undoubtedly more complex. The trends identified are only intended to highlight streams experiencing flow changes that may physically alter the stream's channel morphology.

As noted earlier, R-B Index values tend to decrease as the watershed sizes increase, which is accounted for in the quartile rankings. With regard to the trend analysis, smaller watersheds are also more likely to register an increase in flashiness, as shown in Figure 9. For example, 50 percent of the gages with an increasing trend have watersheds smaller than 100 square miles, compared to only 20 percent of the gages with decreasing trends.

Trends are for the gage location only. Streams that are increasingly flashy at one location may become stable downstream due to attenuation of flashy flows by tributary flows downstream of the gage. Similarly, flashy flows in a stream above the gage may be masked by the combined flows of other streams at the gage.

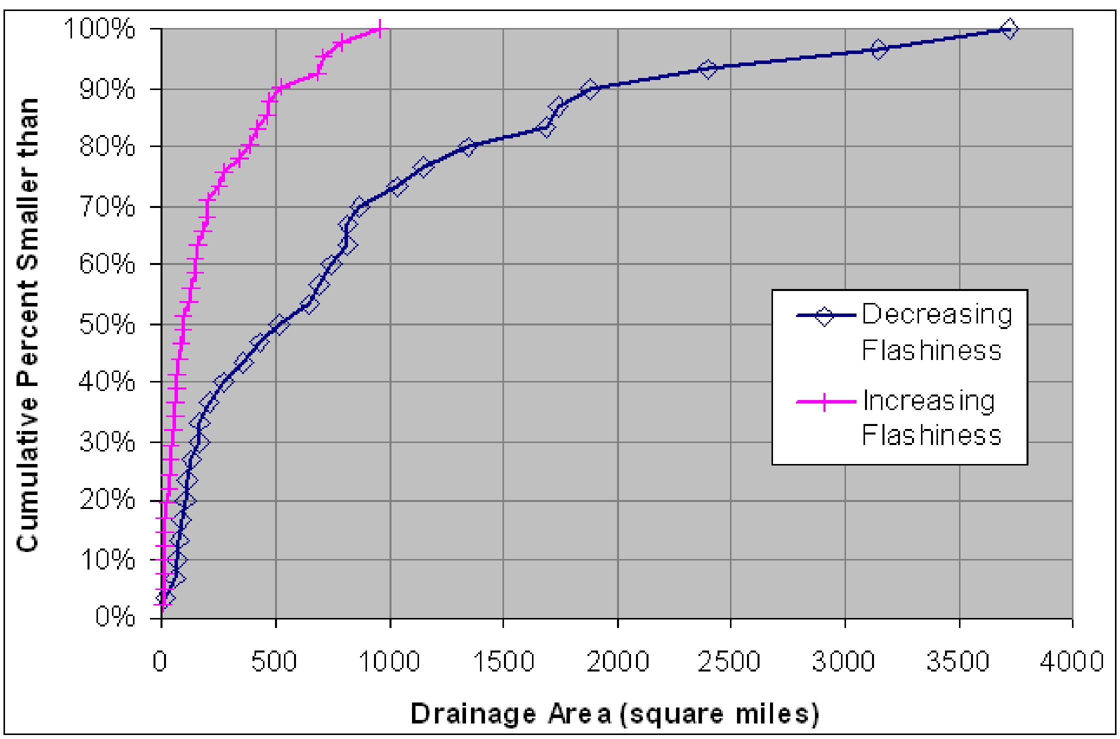

Figure 9 – Scaling Comparison of Gages with Increasing and Decreasing Trends

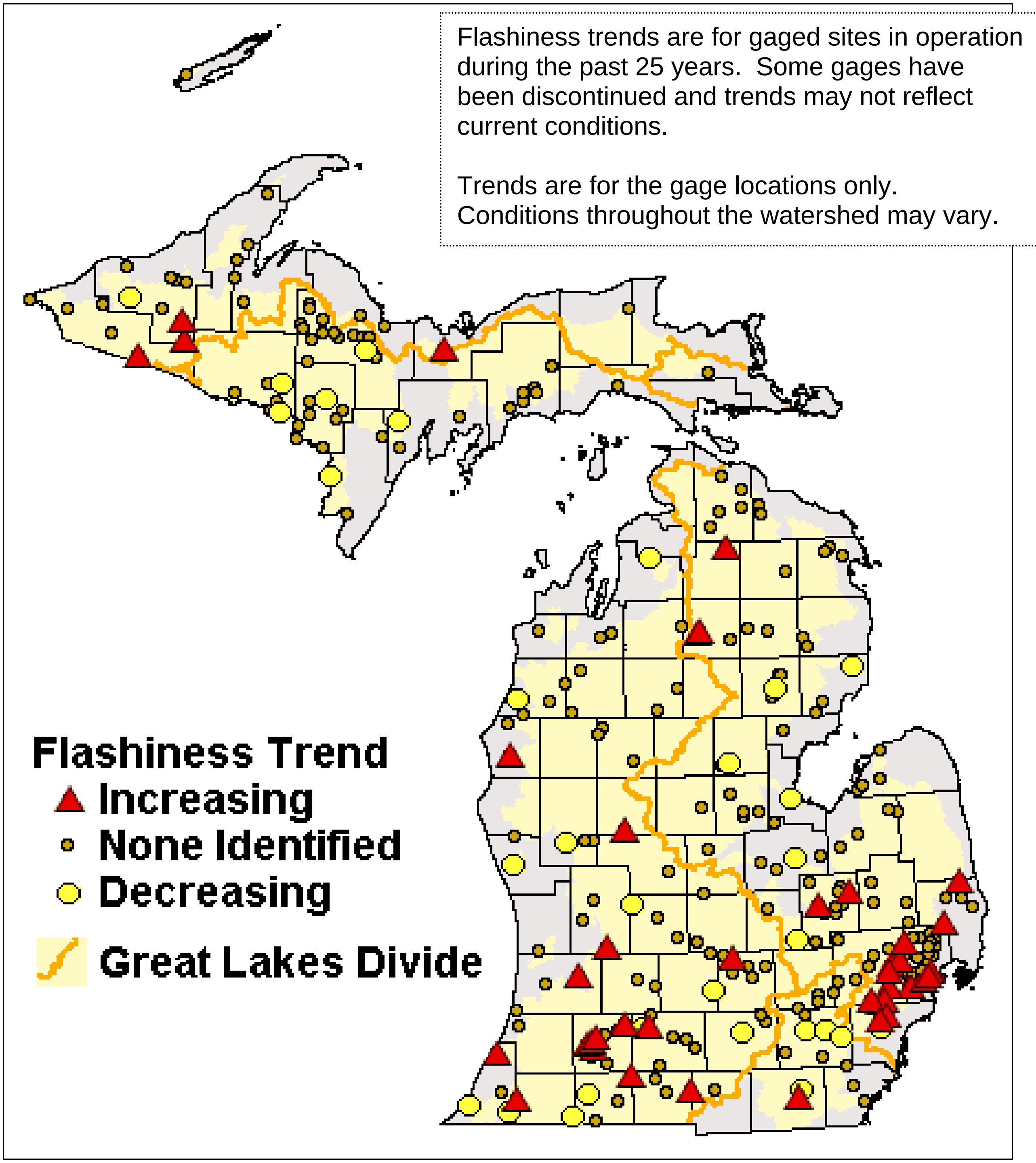

Figure 10 – Flashiness Trend by Gage

Table 2 – Summary of Gages with Trend Changes ordered by 1) trend classification, 2) peninsula, 3) great lake drainage, and 4) gage number.

Peninsula	Great Lake Drainage	Gage Number	Gage Description	Major Watershed	Ending Water Year
Gage locations that are becoming less flashy					
Upper	Lake Superior	4036000	West Branch Ontonagon River Near Bergland, MI	Ontonagon	2004
Upper	Lake Michigan	4058100	Middle Branch Escanaba River Near Princeton, MI	Escanaba	2004
Upper	Lake Michigan	4059000	Escanaba River At Cornell, MI	Escanaba	2004
Upper	Lake Michigan	4062011	Brule River Near Commonwealth, WI	Menominee	2004
Upper	Lake Michigan	4062500	Michigamme River Near Crystal Falls, MI	Menominee	2004
Upper	Lake Michigan	4065393	East Branch Sturgeon River Below Skunk Cr Near Felch, MI	Menominee	1984
Upper	Lake Michigan	4066003	Menominee River Below Pemene Creek Near Pembine, WI	Menominee	2004
Lower	Lake Michigan	4096015	Galien River Near Sawyer, MI	St. Joseph	2004
Lower	Lake Michigan	4097500	St. Joseph River At Three Rivers, MI	St. Joseph	2004
Lower	Lake Michigan	4099000	St. Joseph River At Mottville, MI	St. Joseph	2004
Lower	Lake Michigan	4101500	St. Joseph River At Niles, MI	St. Joseph	2004
Lower	Lake Michigan	4105500	Kalamazoo River Near Battle Creek, MI	Kalamazoo	2004
Lower	Lake Michigan	4109000	Grand River At Jackson, MI	Grand	2004
Lower	Lake Michigan	4111000	Grand River At Eaton Rapids, MI	Grand	2004
Lower	Lake Michigan	4116500	Flat River At Smyrna, MI	Grand	1986
Lower	Lake Michigan	4122000	Muskegon River At Newaygo, MI	Muskegon	1993
Lower	Lake Michigan	4122100	Bear Creek Near Muskegon, MI	Muskegon	2003
Lower	Lake Michigan	4126000	Manistee River Near Manistee, MI	Manistee	1993
Lower	Lake Michigan	4127800	Jordan River Near East Jordan, MI	Pine	2004
Lower	Lake Huron	4137500	Au Sable River Near Au Sable, MI	Au Sable	2004
Lower	Lake Huron	4140500	Rifle River At Selkirk, MI	Rifle	1982
Lower	Lake Huron	4143500	North Branch Kawkawlin River Near Kawkawlin, MI	Kawkawlin	1982
Lower	Lake Huron	4144000	Shiawassee River At Byron, MI	Saginaw	1983

Peninsula	Great Lake Drainage	Gage Number	Gage Description	Major Watershed	Ending Water Year
Lower	Lake Huron	4149000	Flint River Near Fosters, MI	Saginaw	2004
Lower	Lake Huron	4152500	Tobacco River At Beaverton, MI	Saginaw	1982
Lower	Lake Huron	4168000	Lower River Rouge At Inkster, MI	Rouge	2004
Lower	Lake Erie	4173500	Mill Creek Near Dexter, MI	Huron	2004
Lower	Lake Erie	4174500	Huron River At Ann Arbor, MI	Huron	2004
Lower	Lake Erie	4174800	Huron River At Ypsilanti, MI	Huron	1994
Lower	Lake Erie	4175700	River Raisin Near Tecumseh, MI	Raisin	1980
Gage locations that are becoming more flashy					
Upper	Lake Superior	4033000	Middle Branch Ontonagon River Near Paulding, MI	Ontonagon	2004
Upper	Lake Superior	4034500	Middle Branch Ontonagon River Near Trout Creek, MI	Ontonagon	2004
Upper	Lake Superior	4037500	Cisco Branch Ontonagon River At Cisco Lake Outlet, MI	Ontonagon	2004
Upper	Lake Superior	4044724	Au Train River At Forest Lake, MI	Au Train	2004
Lower	Lake Michigan	4096515	South Branch Hog Creek Near Allen, MI	St. Joseph	2004
Lower	Lake Michigan	4096900	Nottawa Creek Near Athens, MI	St. Joseph	1997
Lower	Lake Michigan	4101800	Dowagiac River At Sumnerville, MI	St. Joseph	2004
Lower	Lake Michigan	4102500	Paw Paw River At Riverside, MI	St. Joseph	2004
Lower	Lake Michigan	4105000	Battle Creek At Battle Creek, MI	Kalamazoo	2004
Lower	Lake Michigan	4105700	Augusta Creek Near Augusta, MI	Kalamazoo	2004
Lower	Lake Michigan	4106180	Portage Creek At Portage, MI	Kalamazoo	2004
Lower	Lake Michigan	4106320	West Fork Portage Creek Near Oshtemo, MI	Kalamazoo	1996
Lower	Lake Michigan	4106400	West Fork Portage Creek At Kalamazoo, MI	Kalamazoo	2004
Lower	Lake Michigan	4106500	Portage Creek At Kalamazoo, MI	Kalamazoo	1986
Lower	Lake Michigan	4108600	Rabbit River Near Hopkins, MI	Kalamazoo	2003
Lower	Lake Michigan	4112500	Red Cedar River At East Lansing, MI	Grand	2004
Lower	Lake Michigan	4118000	Thornapple River Near Caledonia, MI	Grand	1994
Lower	Lake Michigan	4121900	Little Muskegon River Near Morley, MI	Muskegon	1996
Lower	Lake Michigan	4122500	Pere Marquette River At Scottville, MI	Pere Marquette	2004

Peninsula	Great Lake Drainage	Gage Number	Gage Description	Major Watershed	Ending Water Year
Lower	Lake Huron	4128990	Pigeon River Near Vanderbilt, MI	Cheboygan	2004
Lower	Lake Huron	4135500	Au Sable River At Grayling, MI	Au Sable	1993
Lower	Lake Huron	4135600	East Branch Au Sable River At Grayling, MI	Au Sable	1984
Lower	Lake Huron	4147500	Flint River Near Otisville, MI	Saginaw	2004
Lower	Lake Huron	4148500	Flint River Near Flint, MI	Saginaw	2004
Lower	Lake Huron	4159492	Black River Near Jeddo, MI	Black	2004
Lower	Lake Huron	4160600	Belle River At Memphis, MI	Belle	2004
Lower	Lake Huron	4161000	Clinton River At Auburn Heights, MI	Clinton	2004
Lower	Lake Huron	4161100	Galloway Creek Near Auburn Heights, MI	Clinton	1991
Lower	Lake Huron	4161540	Paint Creek At Rochester, MI	Clinton	2004
Lower	Lake Huron	4161580	Stony Creek Near Romeo, MI	Clinton	2004
Lower	Lake Huron	4162900	Big Beaver Creek Near Warren, MI	Clinton	1988
Lower	Lake Huron	4164000	Clinton River Near Fraser, MI	Clinton	2004
Lower	Lake Huron	4164500	North Branch Clinton River Near Mount Clemens, MI	Clinton	2004
Lower	Lake Huron	4165500	Clinton River At Mount Clemens, MI	Clinton	2004
Lower	Lake Huron	4166000	River Rouge At Birmingham, MI	Rouge	2004
Lower	Lake Huron	4166100	River Rouge At Southfield, MI	Rouge	2004
Lower	Lake Huron	4166200	Evans Ditch At Southfield, MI	Rouge	2003
Lower	Lake Huron	4166300	Upper River Rouge At Farmington, MI	Rouge	2004
Lower	Lake Huron	4166500	River Rouge At Detroit, MI	Rouge	2004
Lower	Lake Huron	4167000	Middle River Rouge Near Garden City, MI	Rouge	2004
Lower	Lake Erie	4176000	River Raisin Near Adrian, MI	Raisin	2004

Flashiness Changes and Hydrologic Alterations

In general, flashiness changes result from hydrologic alterations. Some factors that can alter flashiness include:

- In-Stream Changes
  - Removal or change in operation of a dam
  - Expansion or straightening of the drainage network
- Watershed Land Use Changes
  - Urbanization
  - Forest regrowth
  - Soil compaction
  - Change in paved or other impervious areas
  - Use of low impact development (LID) techniques
  - Change in forestry practices
  - Change in agricultural practices
  - Change in runoff storage capacity

This report does not attempt to fully explain R-B Index value changes at specific sites. Thorough analysis of a specific site or sites within a watershed would be more efficiently and practically performed by local watershed groups and other stakeholders who can often apply watershed-specific and other local information to the interpretation. However, an overview of the results does generally illustrate the effect of some hydrologic alterations. These are discussed in more detail in the following sections.

Dams

The influence of water control structures, especially dams, is one of many complicating factors when interpreting stream flashiness data. The MDEQ tracks 2,552 dams in a statewide dam safety database. There are undoubtedly many more small dams present on the state's rivers and streams. Dams, especially hydropower dams, can influence stream flow and therefore stream flashiness in both the short term (oscillations over hours or days) and the long term (trends over many years). This report does not try to identify all locations where a dam may influence the results of the R-B Index calculations. However, Appendix A notes gages that may be affected by dam operations. This information is from MDEQ's Surface Water Assessment Section (Suppnick, personal communication, 2006) and from yearly USGS Water Resources Data books. This information should be considered a partial, provisional list.

Gage 04170000 is an example of dam operation affecting R-B Index values, as shown in Figure 11. The USGS notes that prior to May 29, 1957, the flow was regulated by a power plant. Since then, there has been only occasional regulation for lake level control. R-B Index values show a consistent decline after 1957.

The installation or removal of a dam, or a change in the operation of the dam, can affect the R-B Index values. However, if a dam is operated to manage only lower flows, it is possible that the effect on stream morphology will be negligible.

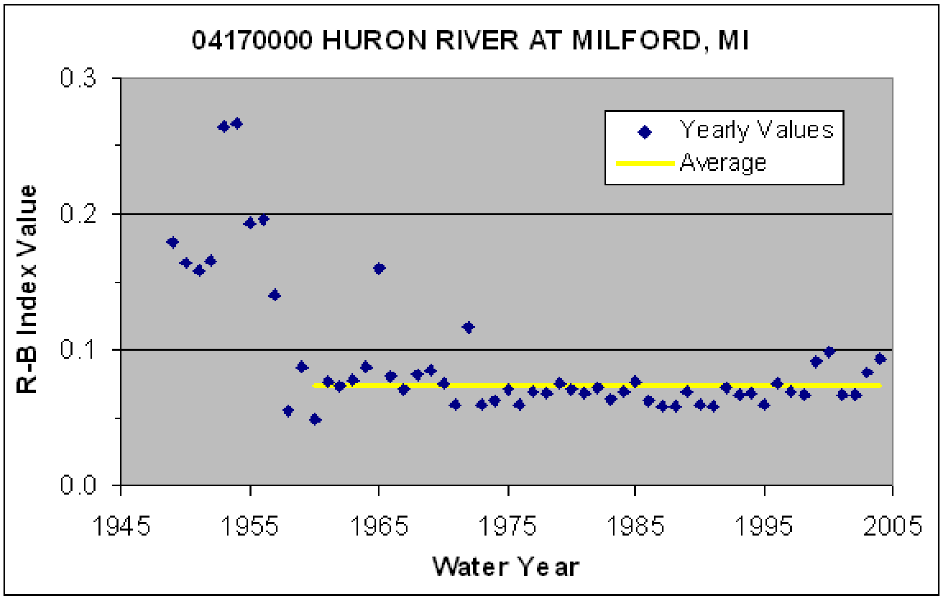

Figure 11 – USGS Gage 04170000, operation of dam changed in 1957

Land Use, Soil, and Imperviousness

It is almost an axiom that urban areas have flashy streams and undeveloped areas do not. Figure 12 illustrates the land use throughout the state as of 1978, along with the flashiness rankings. Although the figure suggests that there is some correlation of flashiness with developed land uses, land use does not completely predict flashiness rankings. Certainly many of the flashier gages are in urban areas. However, some are also in areas with extensive natural areas, and some of the gages in the lower quartiles are in or near urban areas. Soils, Figure 13, are also a likely factor. However, neither soils nor urbanization fully explain the flashiness rankings, particularly the cluster of highest quartile rankings around Saginaw Bay.

It is also an axiom that urban development causes flashier streams. Certainly many of the gages with increasing flashiness trends are in urban or urbanizing areas, Figure 14. Again, there are exceptions. This is expected because stream flow is the stream's response to many factors in a complex system - the watershed. Conversion of forest to cropland, reforestation of cropland, or a change in logging practices may have as much impact on streamflow as the transition from cropland to urban land uses. When wise stormwater management is employed, adverse stream impacts can be minimized.

Imperviousness within the watershed has received particular attention as an indicator of stream quality. The Center for Watershed Protection has proposed a classification of headwater urban streams based on the percent imperviousness. The classifications are excerpted in Table 3 and described in detail in Article 1 in Schueler, 2000.

Table 3: Classification of Urban Headwater Streams

Urban Stream Classification	**Sensitive (0–10% Impervious)**	**Impacted (11–25% Impervious)**	**Non-supporting (26–100% Impervious)**
Channel Stability	Stable	Unstable	Highly unstable
Water Quality	Good	Fair	Fair-Poor
Stream Biodiversity	Good-Excellent	Fair-Good	Poor
Resource Objective	Protect biodiversity and channel stability	Maintain critical elements of stream quality	Minimize downstream pollutant loads

Excerpted from “The Practice of Watershed Protection” by Thomas Schueler and Heather Holland, p. 15

Percent imperviousness was analyzed based on the 1978 land use data, Figure 12, 1995 Topologically Integrated Geographic Encoding and Referencing (TIGER) population density data, Figure 15, subbasin delineations, Figure 16, and the Impervious Surface Analysis Tool (ISAT) Geographic Information Systems (GIS) extension. The population data is from the Michigan Geographic Data Library, www.mcgi.state.mi.us/mgdl/?action=thm, located under Political Features. The population data was converted to 50 meter grids. ISAT was provided by the National Oceanic and Atmospheric Administration, www.csc.noaa.gov/crs/cwq/isat.html. Percent imperviousness was estimated using ISAT according to Table 4. The imperviousness values for residential, commercial, and industrial are from the NRCS (NRCS, 1986).

Table 4: Imperviousness Table for ISAT Analysis

Class	Description	Assigned Imperviousness (percent) by Population Density (people per square mile)		
		Less than 250	250-1000	Over 1000
1	Residential	25	38	65
2	Commercial	85	85	85
3	Industrial	72	72	72
4	Road, Utilities	95	95	95
5	Gravel Pits	0	0	0
6	Outdoor Recreation	0	0	0
7	Cropland	1	1	1
8	Orchard	1	1	1
9	Pasture	1	1	1
10	Openland	0	0	0
11	Forests	0	0	0
12	Open Water	0	0	0
13	Wetland	0	0	0
14	Bare Soil	0	0	0
15	Exposed Rock	0	0	0

Figure 17 illustrates the percent imperviousness results for the state, based on the watershed subbasins, Figure 16. An imperviousness analysis using larger or smaller subbasins would result in somewhat different results, with average imperviousness generally decreasing as the subbasin size increases. The percent imperviousness results are overlaid with the flashiness trends in Figure 18. Both figures are directly comparable to the Center for Watershed Protection's classifications in Table 3. The imperviousness figures include a break at 5 percent imperviousness to highlight watersheds approaching the 10 percent threshold. Most of the gages that are exhibiting increasing flashiness are in or near urban areas with over 25 percent imperviousness.

We also wondered if areas that are urbanizing and becoming more impervious are more likely to have gages that are becoming flashier. Land use data for 2000 that is comparable to the 1978 data is available for seven counties in southeast Michigan, courtesy of the Southeast Michigan Council of Governments (SEMCOG). 1978 and 2000 land use for this region is shown in Figures 19 and 20 respectively. The corresponding imperviousness is shown in Figures 21 and 22. The figures indicate that increasing imperviousness often increases flashiness.

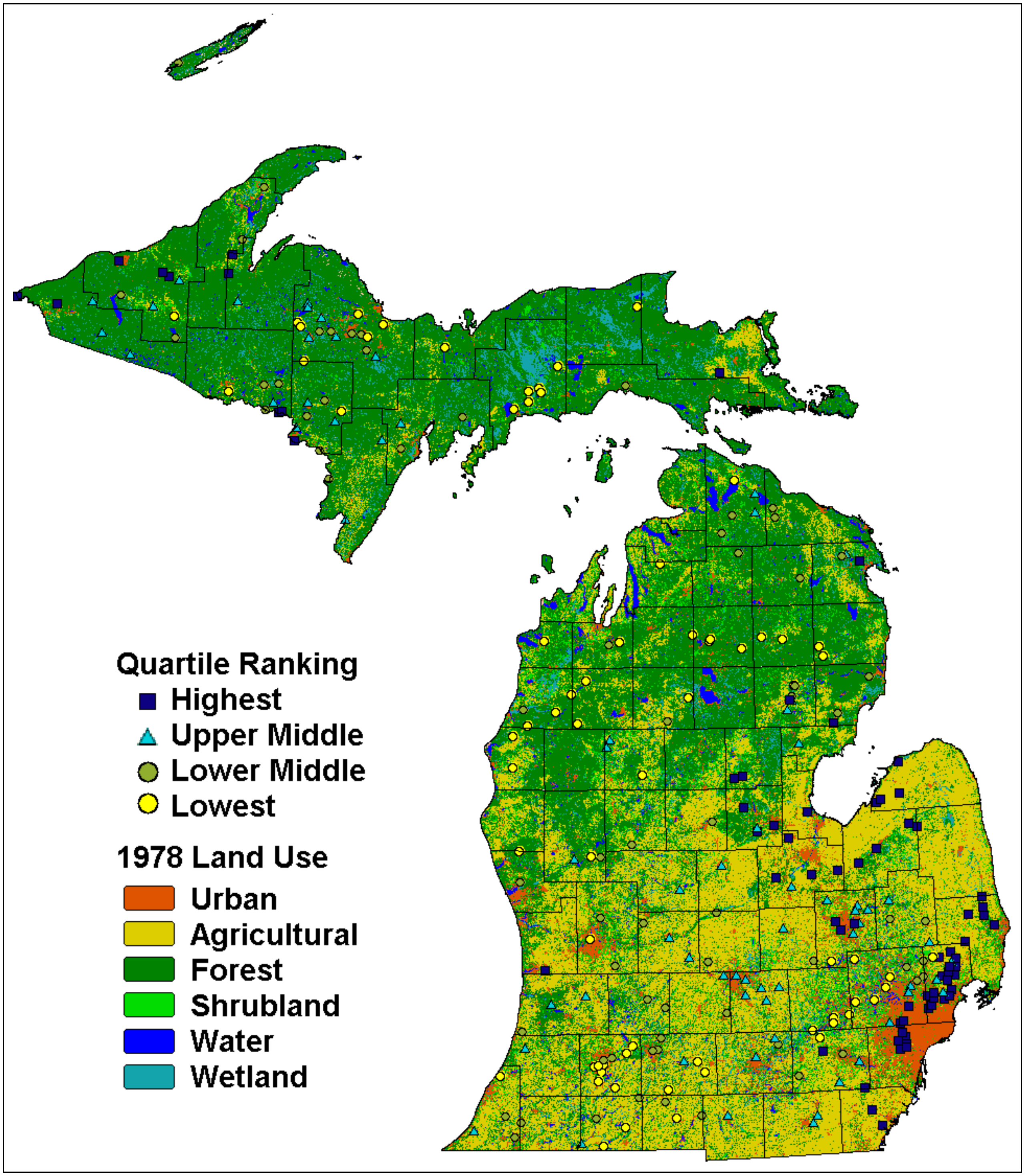

Figure 12 – General 1978 Land Use Classifications with R-B Index Quartile Rankings

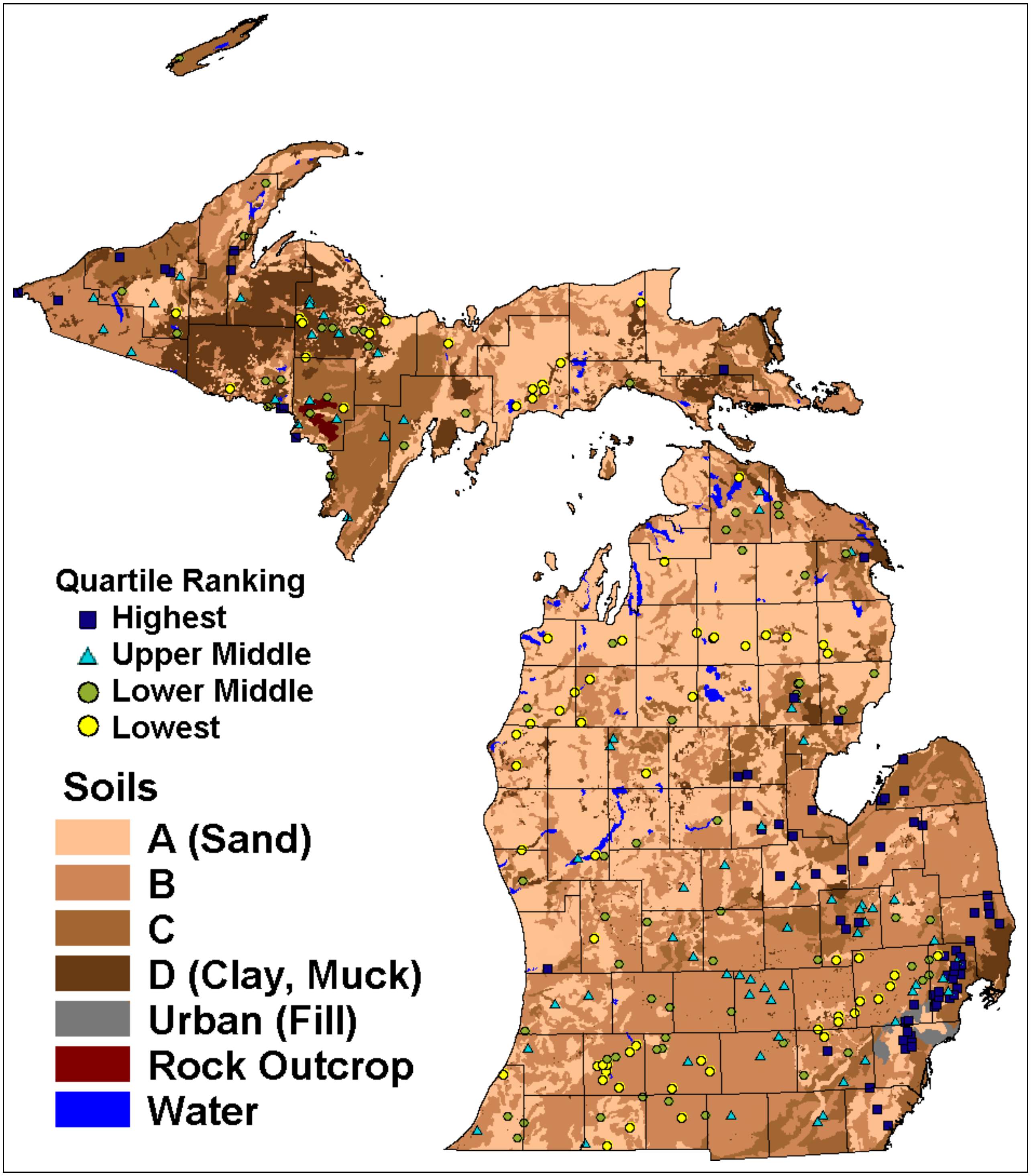

Figure 13 – Soil Hydrogroups from State Soil Geographic (Statsgo) Database, dual classified soil resolved using 1978 land use data, with R-B Index Quartile Rankings

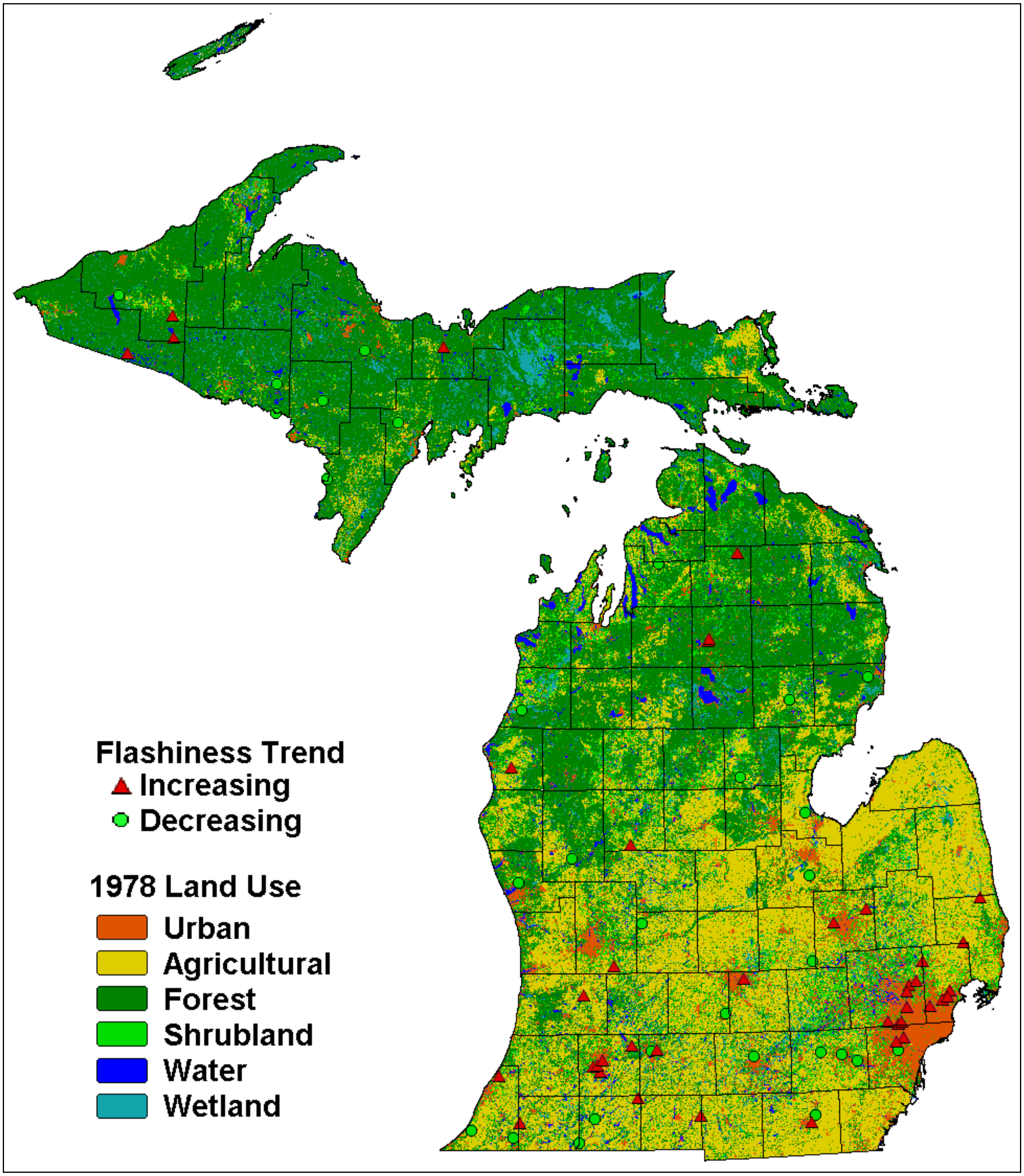

Figure 14 – 1978 Land Use with Flashiness Trends

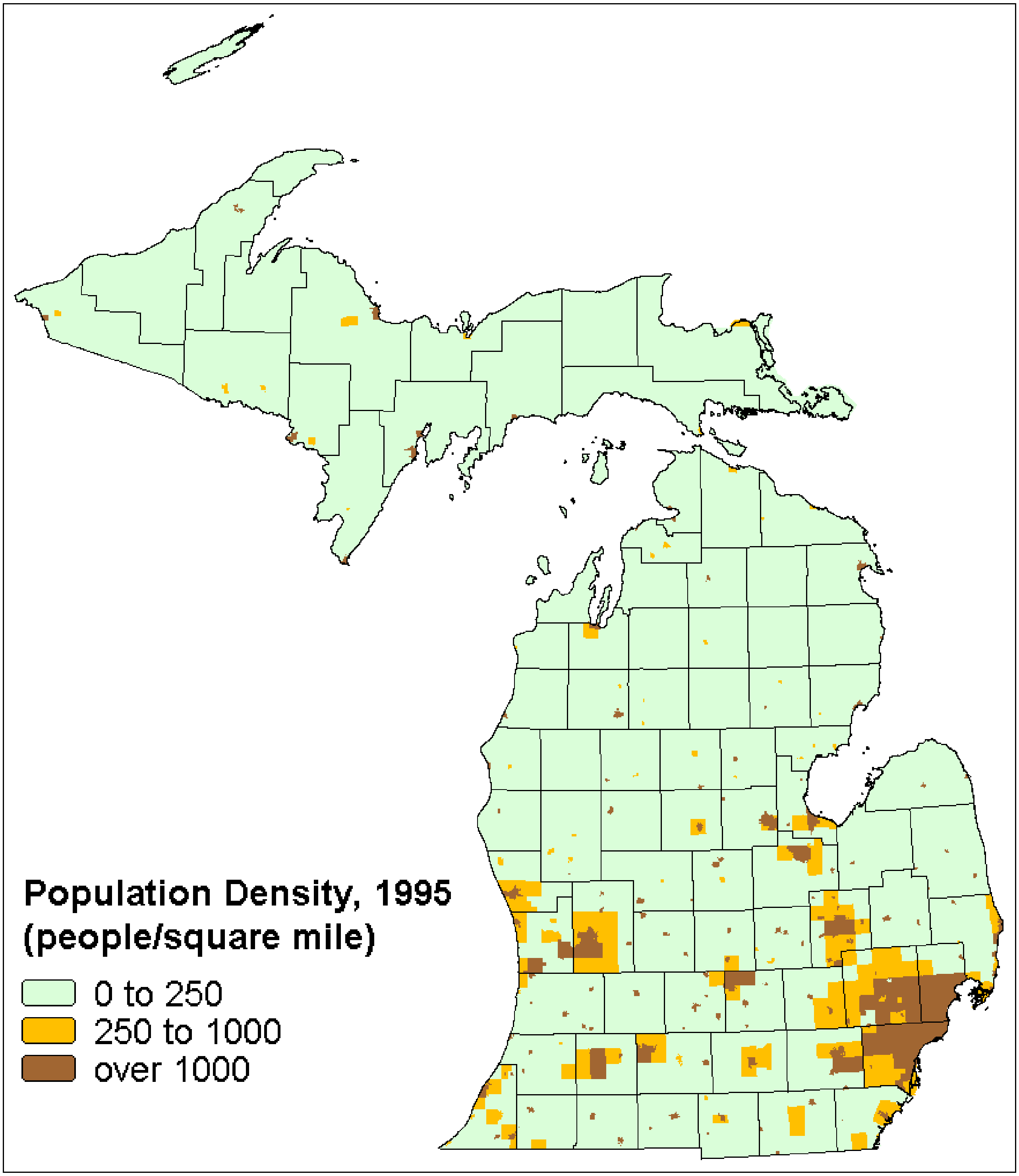

Figure 15 – Population Density, 1995 TIGER Census Data

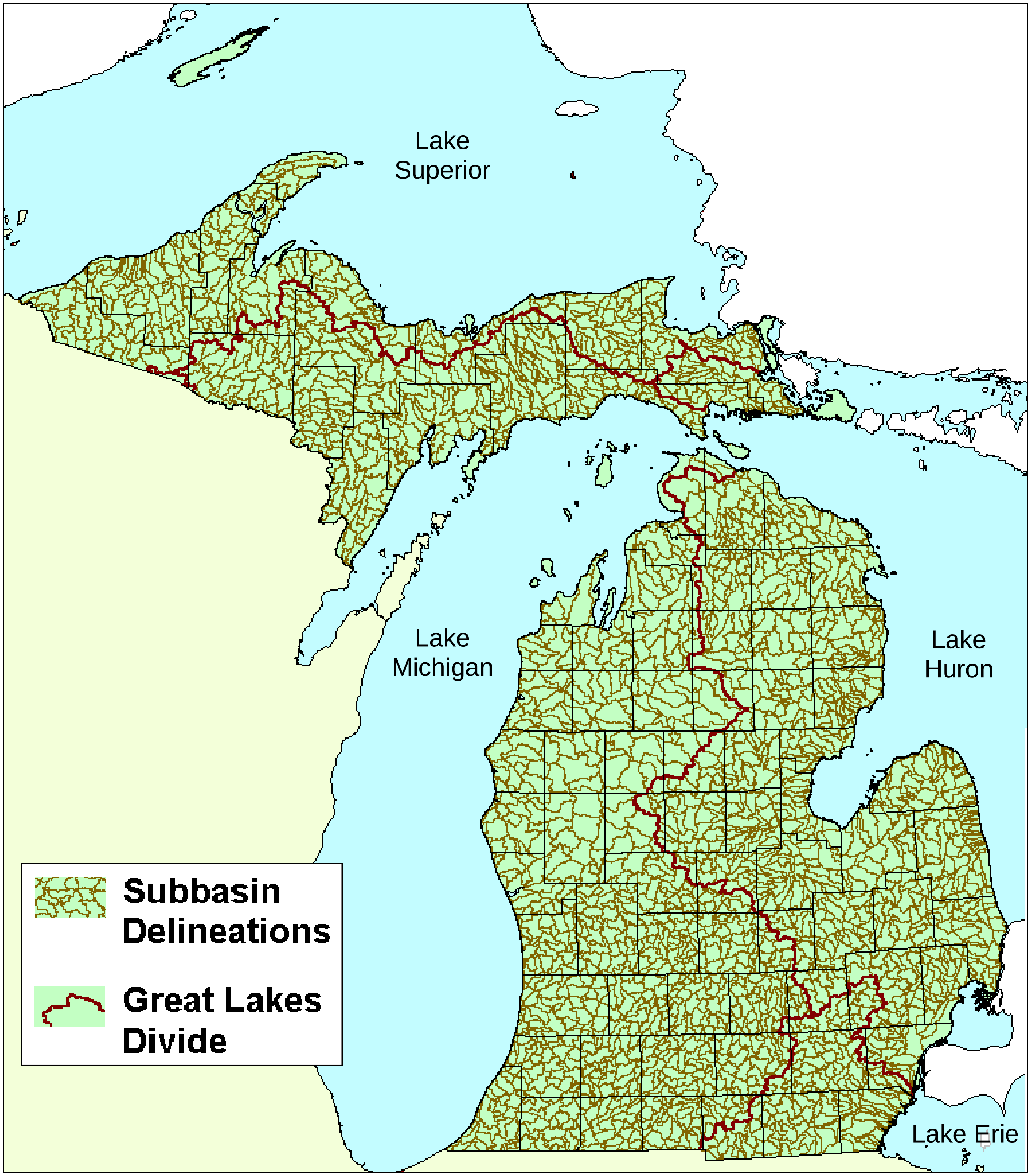

Figure 16 – Subbasins Used in Imperviousness Analysis

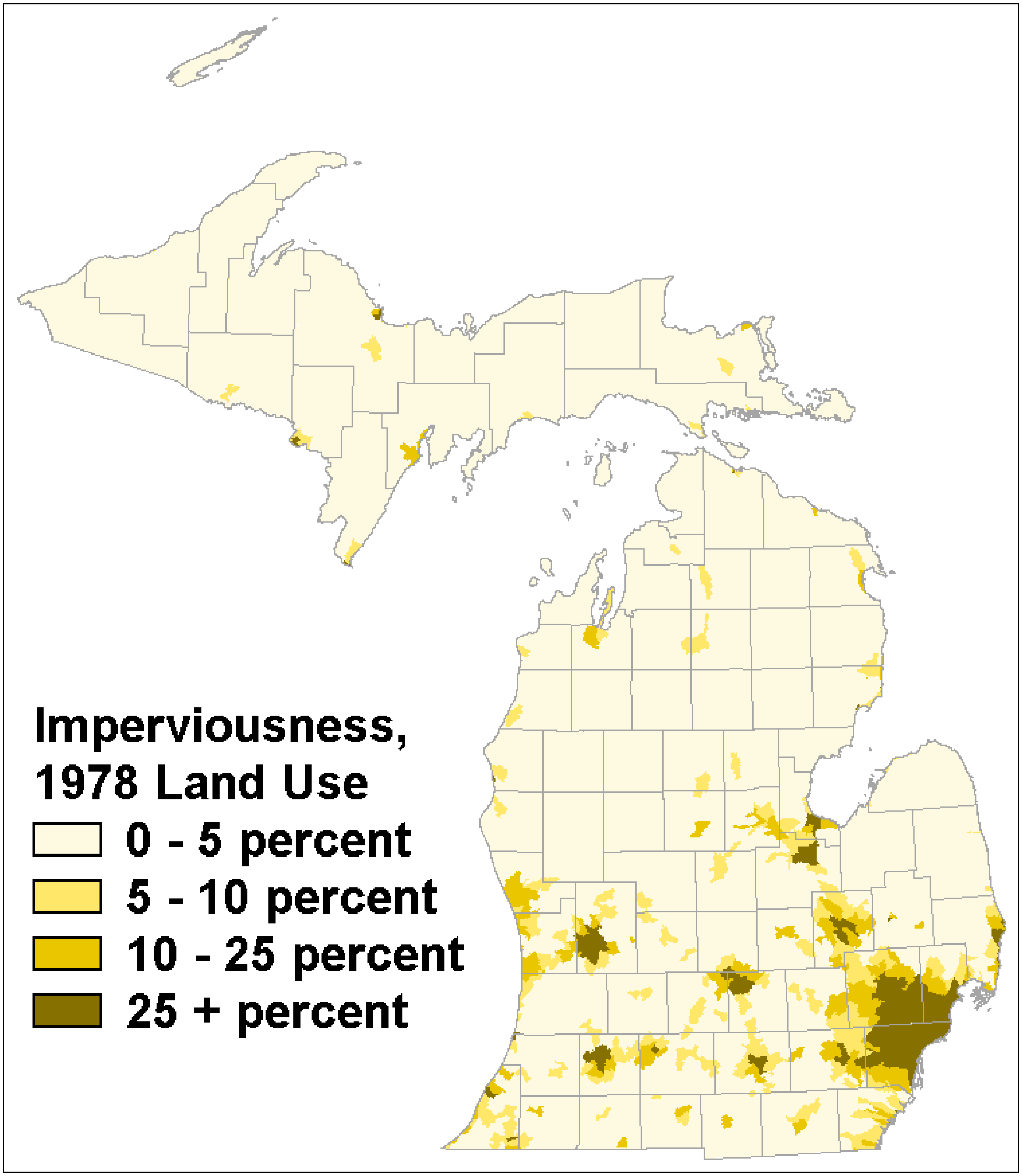

Figure 17 – Statewide Imperviousness, 1978 Land Use

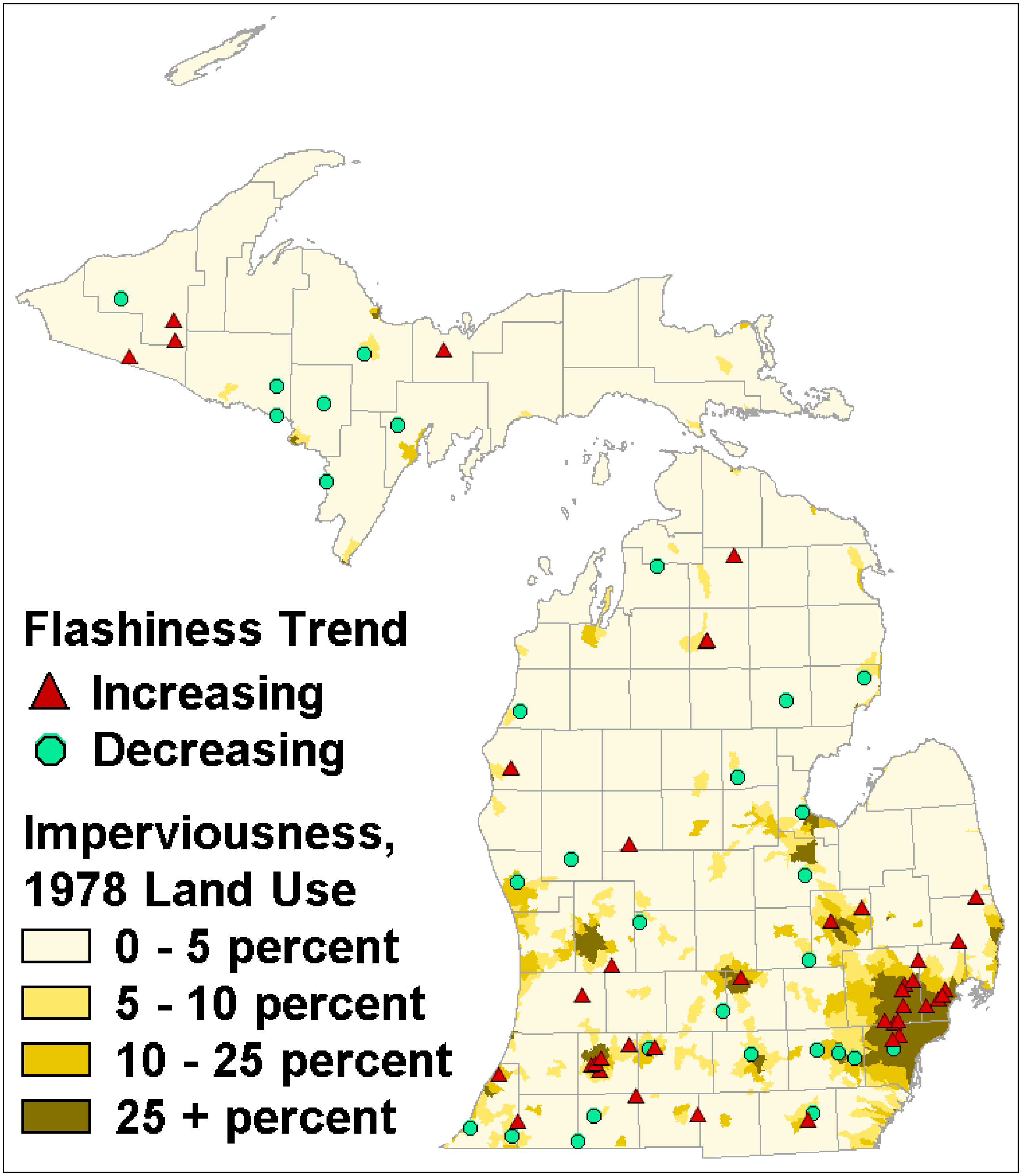

Figure 18 – Statewide Imperviousness with Flashiness Trends, 1978 Land Use

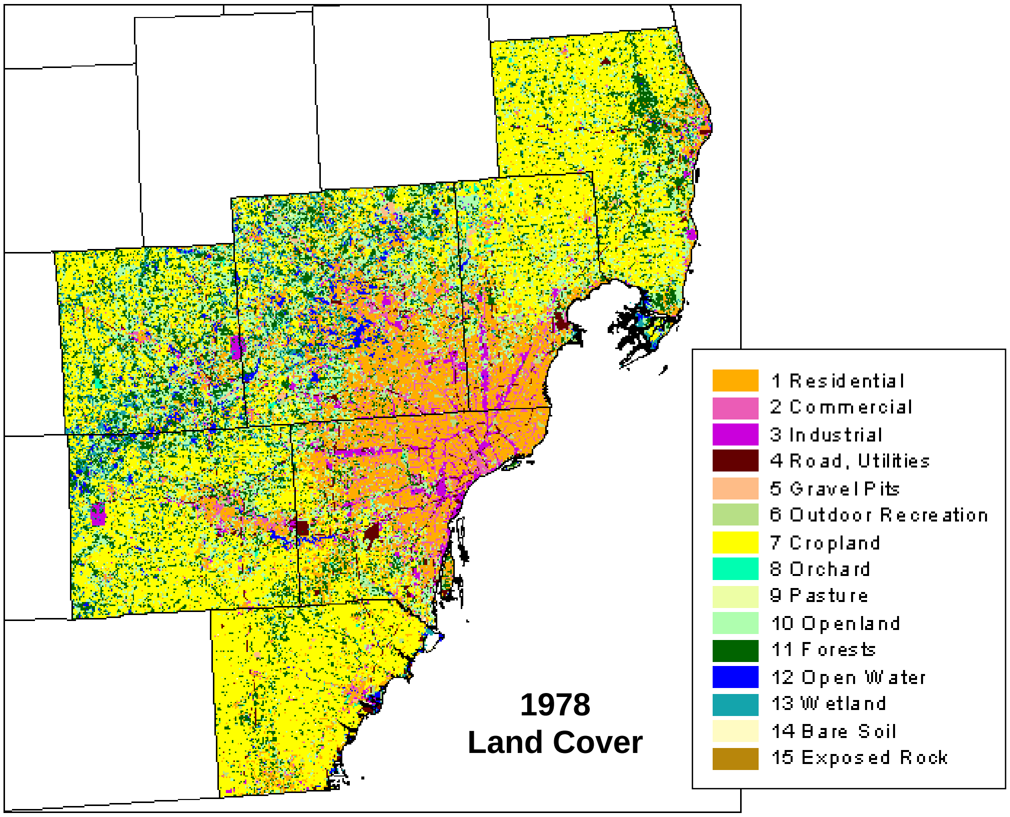

Figure 19 – 1978 Land Use in Southeast Michigan

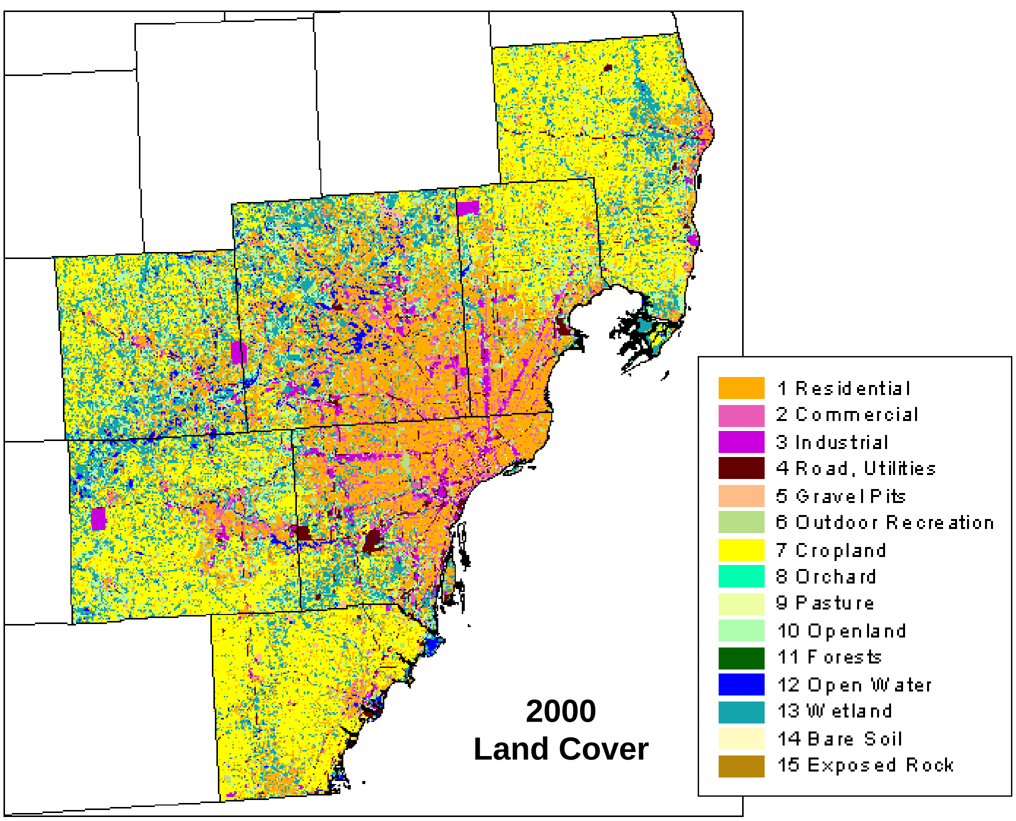

Figure 20 – 2000 Land Use in Southeast Michigan

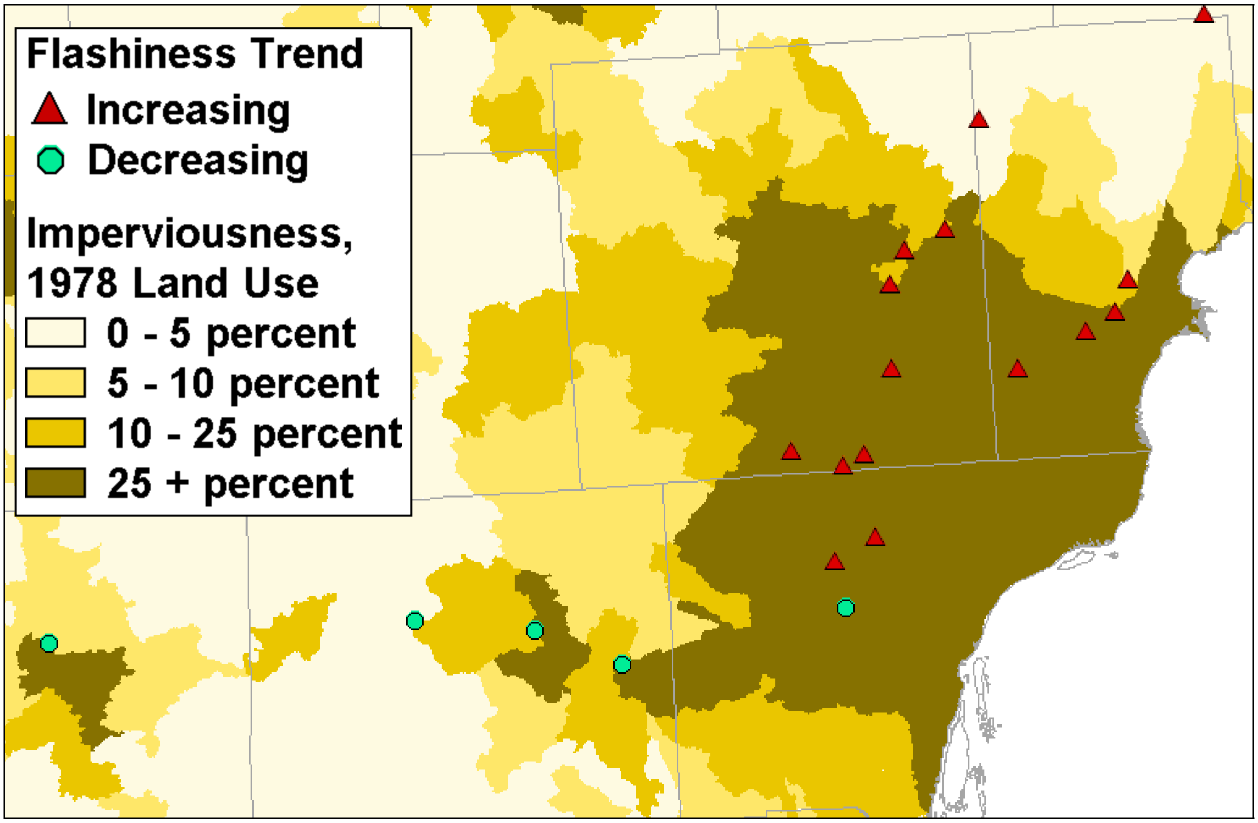

Figure 21 – Southeast Michigan Imperviousness with Flashiness Trends, 1978 Land Use

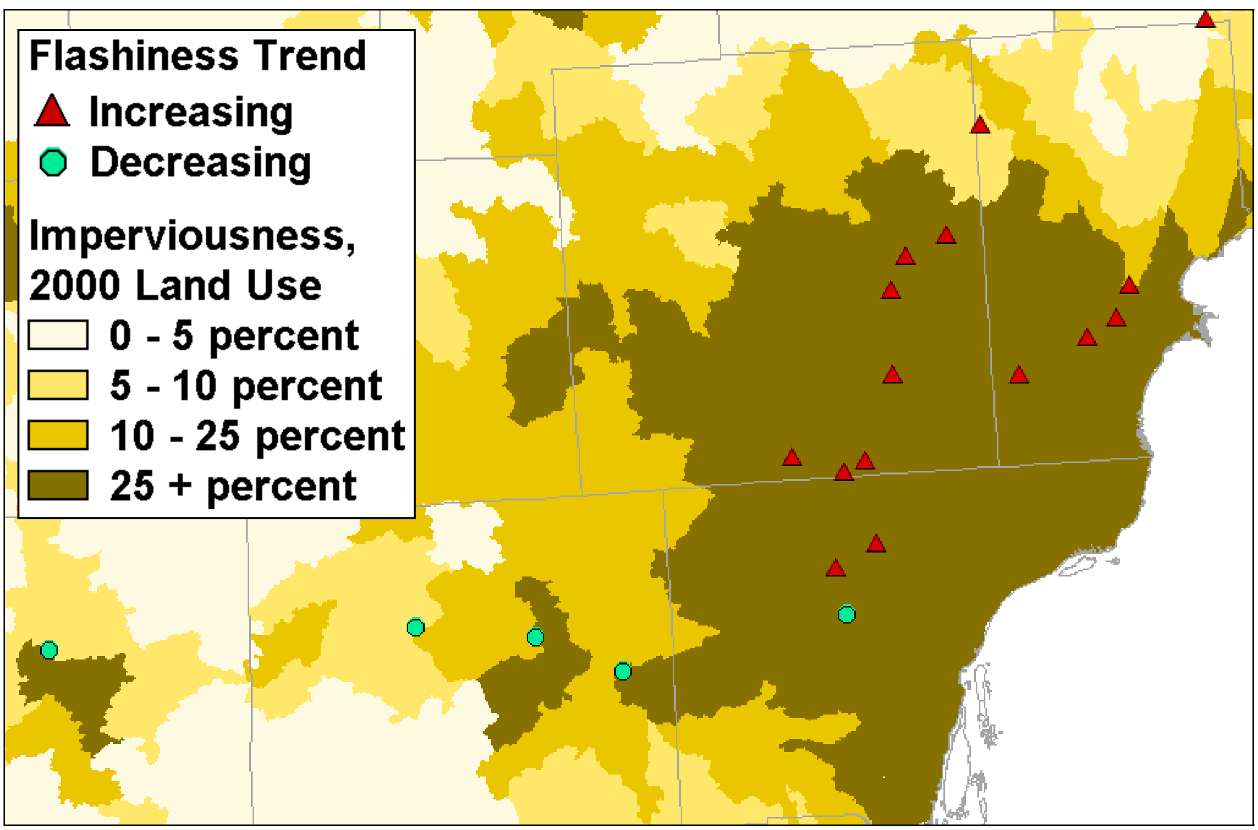

Figure 22 – Southeast Michigan Imperviousness with Flashiness Trends, 2000 Land Use

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Appendices

Appendix A: Graphs of Index Values for Each Site

Graphs of the R-B Index values are shown for each site. The x-axis always ends at 2005, so that the comparative age of the data is more readily apparent. The y-axis is constrained to show gridlines every for every 0.1 increment, allowing a sense of rank relative to other gages - more gridlines equate to higher values.

The average of the R-B Index values is shown as a horizontal yellow line spanning the years used to calculate the average. If there is a statistically significant (i.e., $p < 0.10$) trend encompassing at least part of the past 25 years, it is represented by a sloped purple line. If a statistically significant trend change occurred, only the more recent trend is shown. Where there is an identified trend change, the average R-B Index value is based only on the years spanned by the trend and average lines.

Some gage-specific information is included under each graph. Some, though likely not all, of the gages that may be affected by dam operations are noted. In a few cases, equivalent gages are noted. This is where a gage is moved and assigned a new number, but considered equivalent. In these cases, the flow record for the discontinued gage is included in the new gage. Only the newer gage, with the complete record, is included in this analysis.

The graphs in this appendix are arranged in numerical order. In general, they are arranged by Great Lake (or connecting channel) watershed, in the following order:

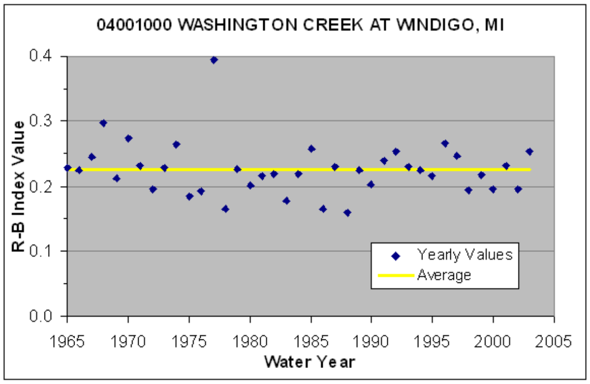
- Streams tributary to Lake Superior (04001000 - 04045500), pages A-2 – A-6
- Streams tributary to Lake Michigan
    - Upper Peninsula (04046000 - 04067000), pages A-6 – A-13
    - Lower Peninsula (04096015 - 04127800), pages A-14 – A-27
- Streams tributary to Lake Huron
    - Upper Peninsula (04127918), page A-27
    - Lower Peninsula (04127997 - 04159010), pages A-27 – A-38
- Streams tributary to St. Clair River and Lake St. Clair (04159492 - 04165500), pages A-38 – A-44
- Streams tributary to Detroit River (04166000 - 04168400), pages A-44 – A-46
- Streams tributary to Lake Erie (04169500 - 04176605), pages A-46 – A-48

As noted on the USGS website, http://pubs.usgs.gov/wdr/2006/documentation.html#sitenumber, "Since October 1, 1950, hydrologic-station records in USGS reports have been listed in order of downstream direction along the main stream. All stations on a tributary entering upstream from a main-stream station are listed before that station. A station on a tributary entering between two mainstream stations is listed between those stations."

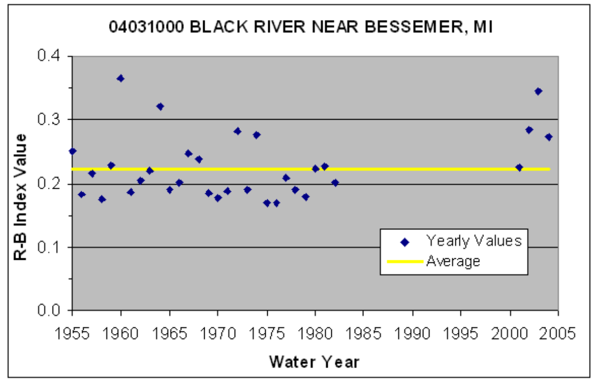
The one USGS gage on a Michigan river that is a tributary to the Upper Mississippi River Basin, gage 05390100 on Lac Vieux Desert, is not included in this report because the gage is in Wisconsin.

To expedite finding a particular graph, search by the USGS gage number, as follows:

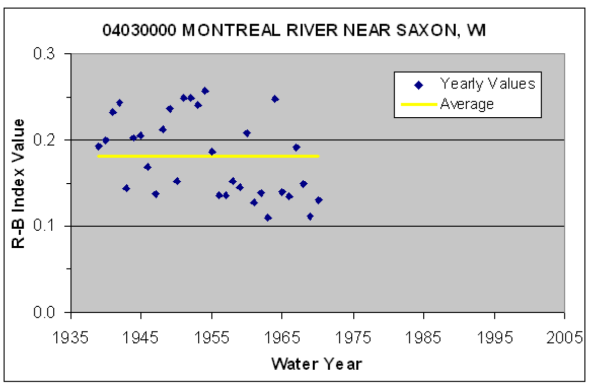
1. Click “Edit” on the tool bar at the top of the page
2. Click “Find”
3. Enter the 8-digit gage number in the “Find what” line
4. Click the “Find Next” button



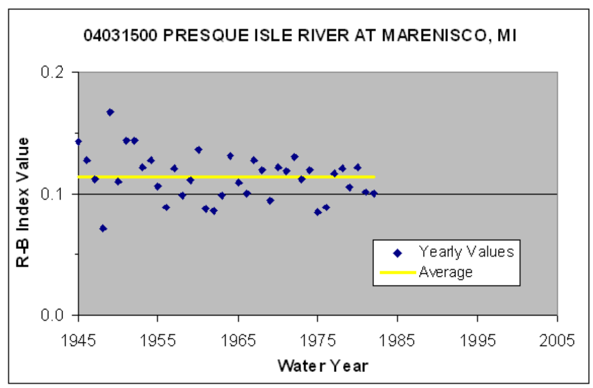
USGS Gage 04001000



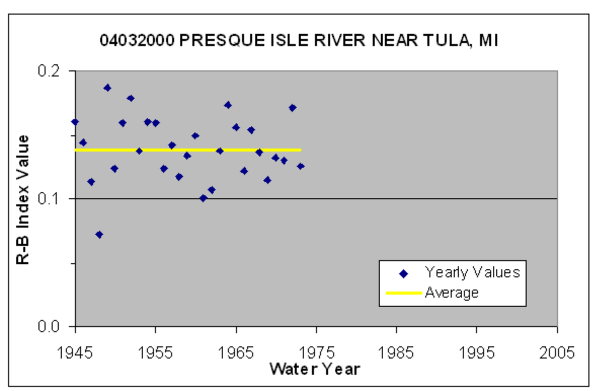
USGS Gage 04031000 – Flow included some ground water pumped from mines at Bessemer.



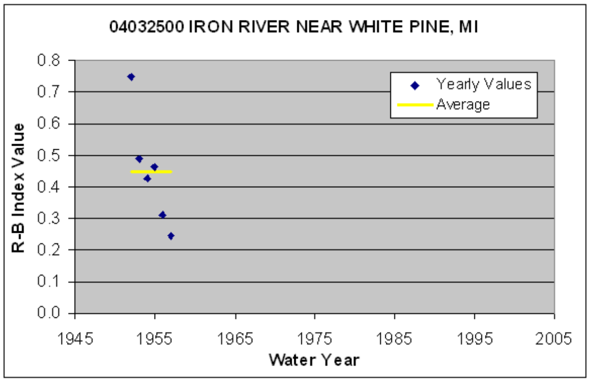
USGS Gage 04030000 – Diurnal fluctuation caused by Saxon Falls power plant 1.5 miles upstream. Flow regulated by Gile reservoir on West Branch Montreal River since April 1941.



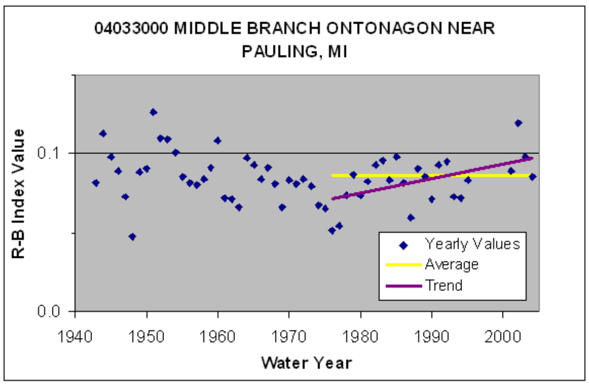
USGS Gage 04031500 – Since 1959, occasional regulation by Presque Isle Flooding Reservoir 2.5 miles upstream.



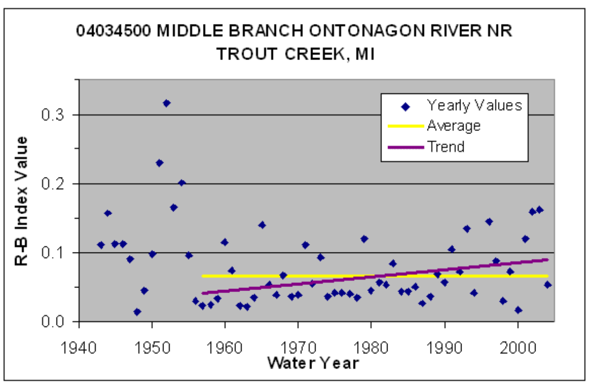
USGS Gage 04032000 – Occasional regulation for lake or pond level control at several places above station at Marenisco.



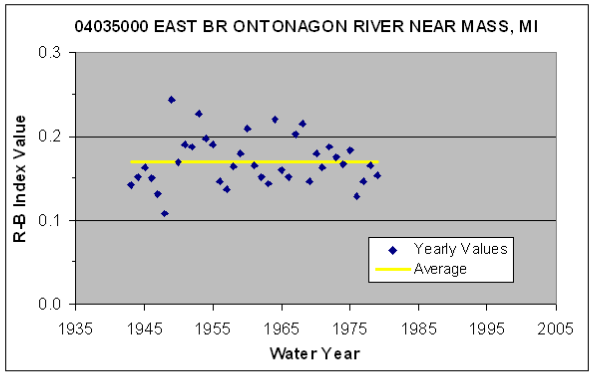
USGS Gage 04032500



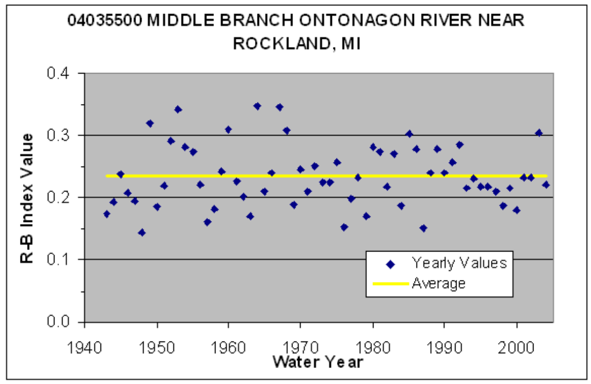
USGS Gage 04033000



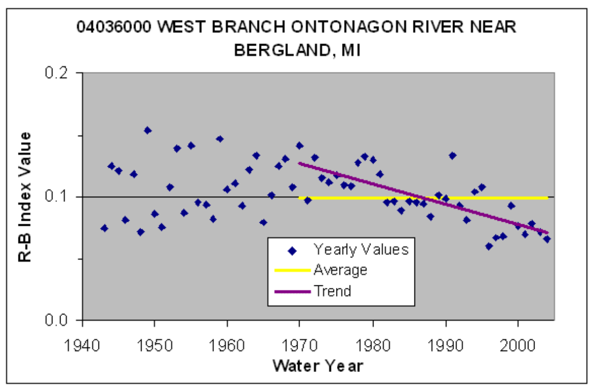
USGS Gage 04034500 – Regulation by Bond Falls Reservoir 7.5 miles upstream.



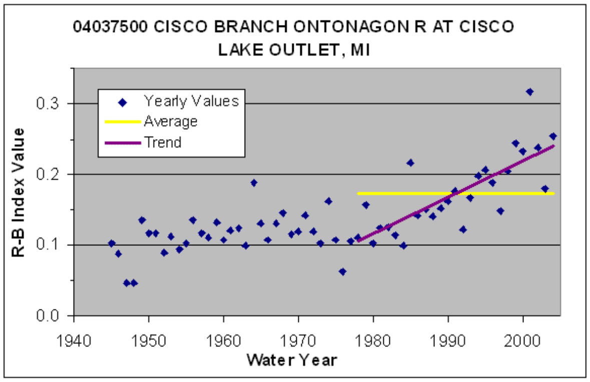
USGS Gage 04035000



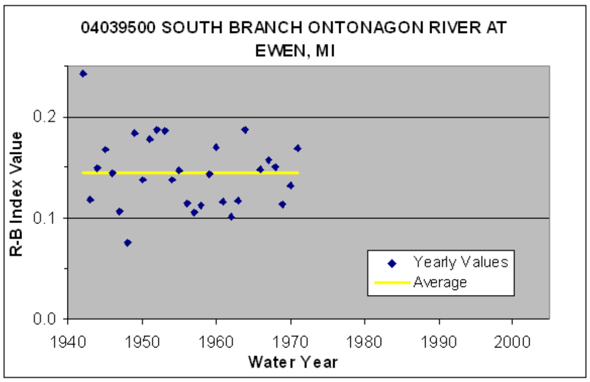
USGS Gage 04035500 – Regulation by Bond Falls Reservoir 30 miles upstream.



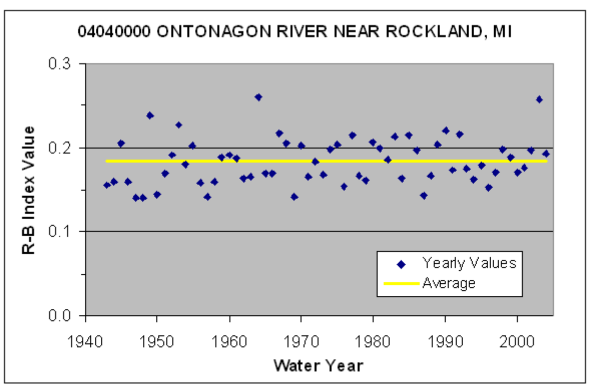
USGS Gage 04036000 – Flow regulated by Lake Gogebic.



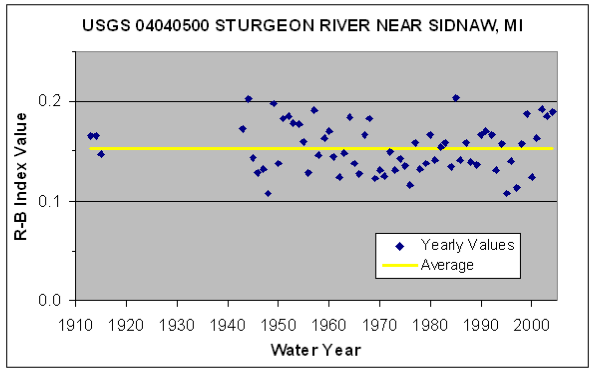
USGS Gage 04037500 – Flow regulated by Cisco Lake.



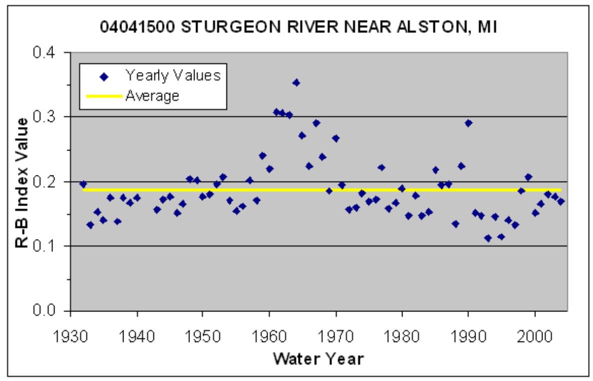
USGS Gage 04039500 – Some diversions from middle branch Ontonagon River by Bond Falls Canal. Some regulation at medium and low flows by Cisco Lake.



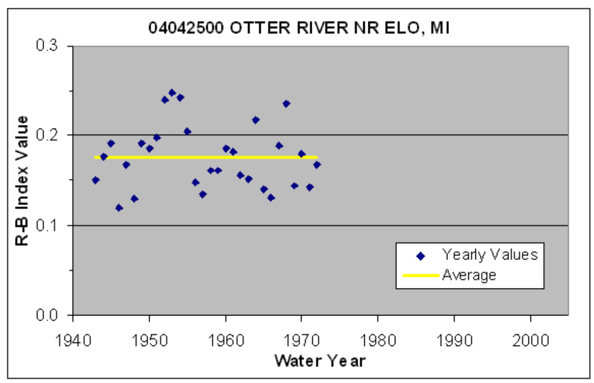
USGS Gage 04040000 – Regulated by Lake Victoria power plant on west branch five miles upstream. Bonds Falls reservoir 24 miles upstream.



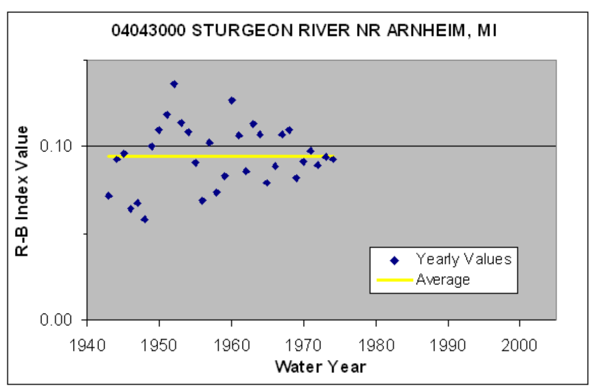
USGS Gage 04040500



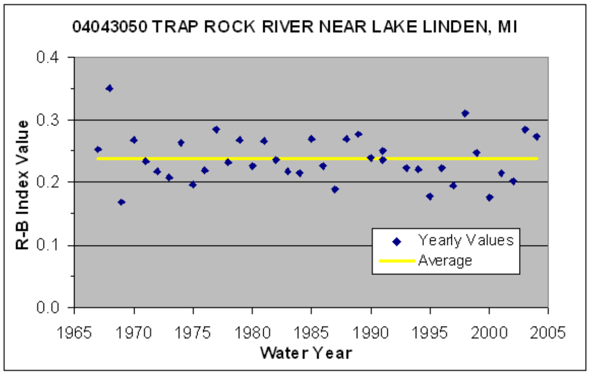
USGS Gage 04041500 – Flow regulated by power plant at gage station.



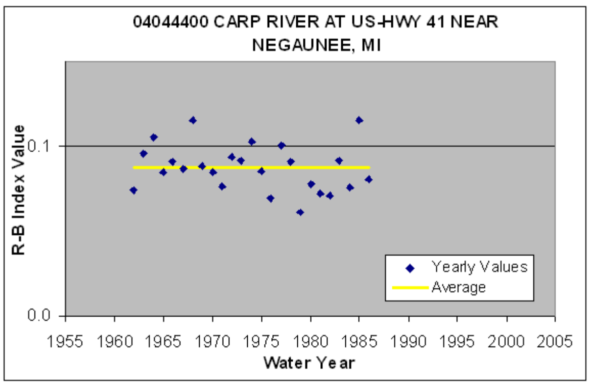
USGS Gage 04042500



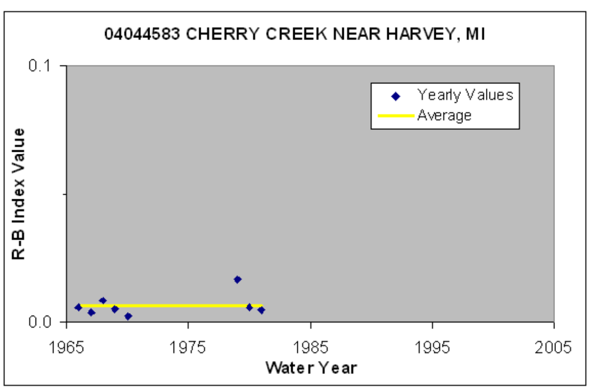
USGS Gage 04043000 – Occasional slight regulation caused by Prickett Dam at mile 45.



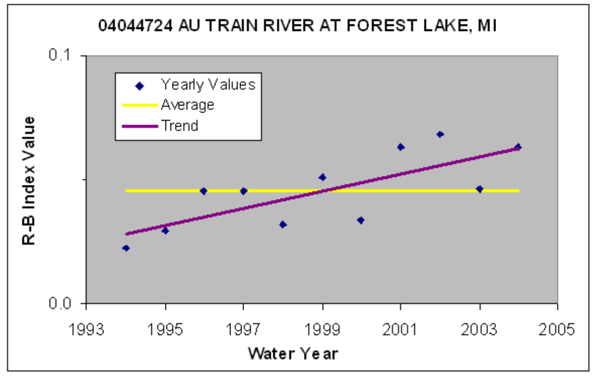
USGS Gage 04043050



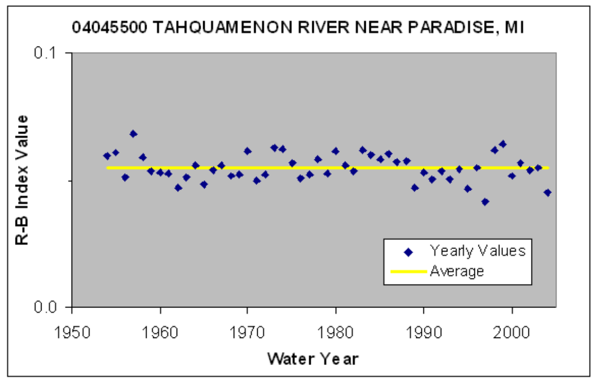
USGS Gage 04044400 – Flow regulated by Deer Lake storage reservoir five miles upstream.



USGS Gage 04044583



USGS Gage 04044724 – Flow regulated by a power plant 800 feet upstream and by the Au-train Basin 0.6 miles upstream.



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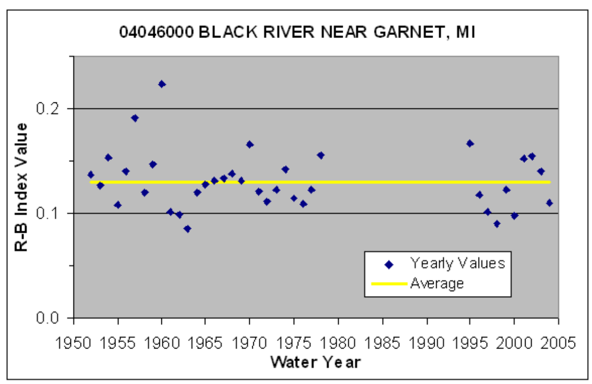
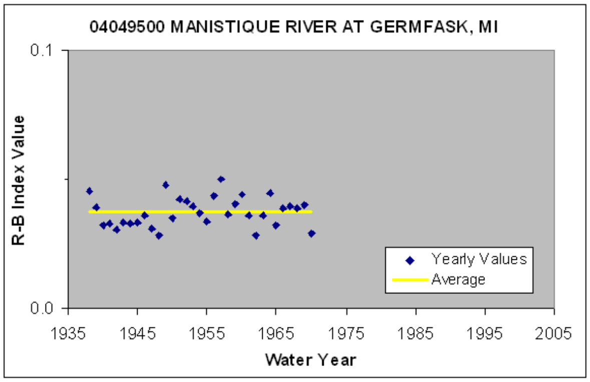
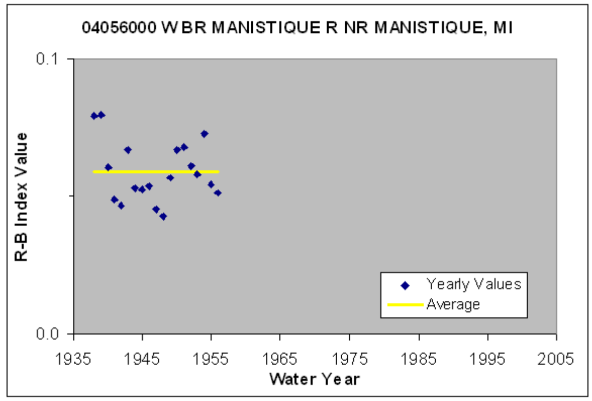


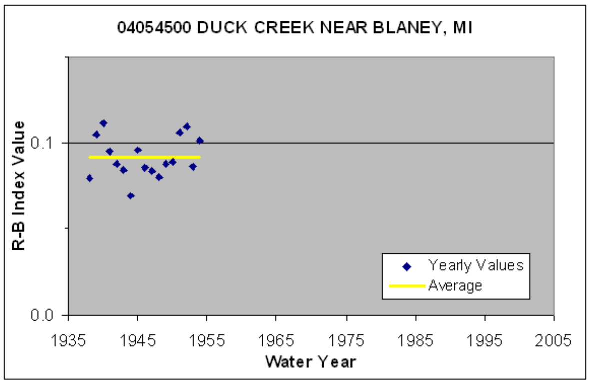
USGS Gage 04046000



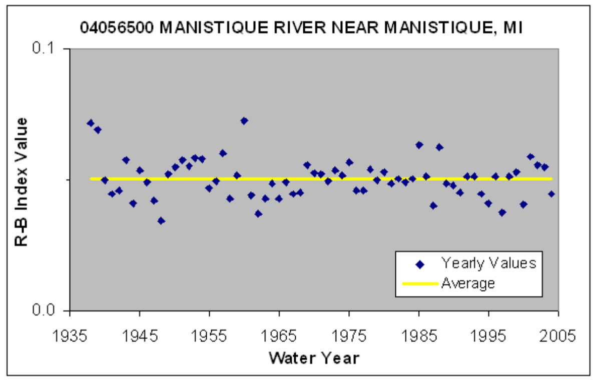
USGS Gage 04049500 – Slight regulation on outlet of Manistique Lake about seven miles upstream beginning July 1948.



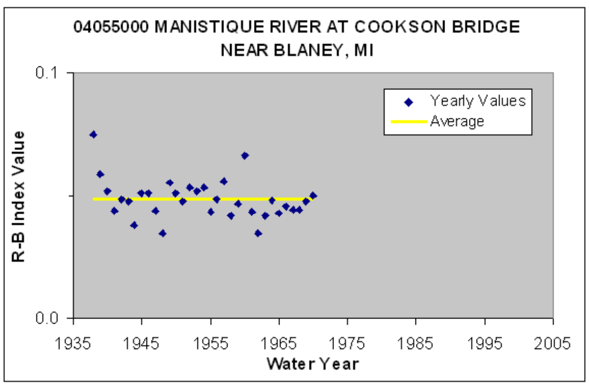
USGS Gage 04056000



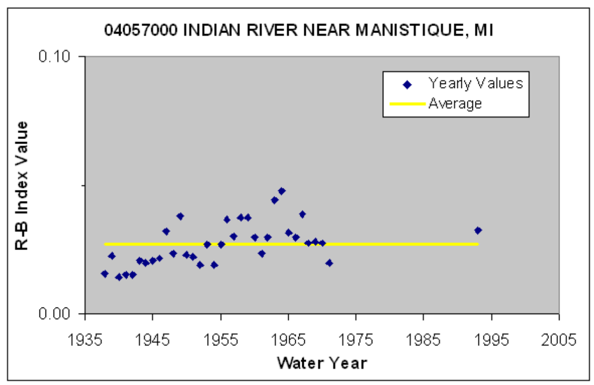
USGS Gage 04054500



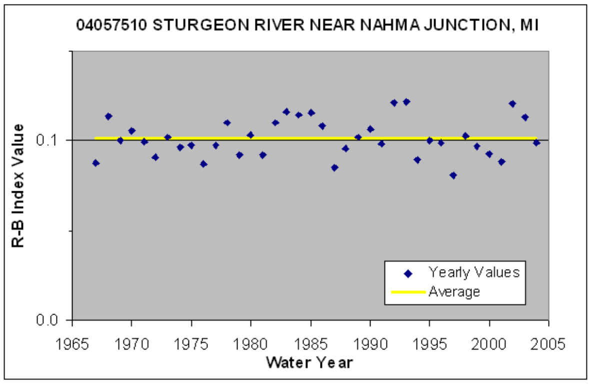
USGS Gage 04056500 – Slight regulation by dam on outlet of Manistee Lake since July 1948.



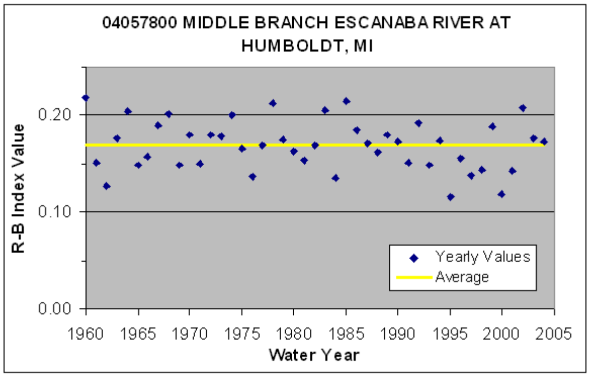
USGS Gage 04055000 – Since July 1948 slight regulation on outlet at Manistique Lake about 25 miles upstream.



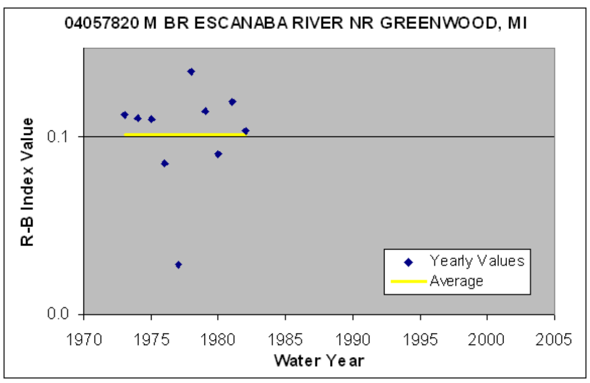
USGS Gage 04057000 – Indian Lake regulated 1.5 miles below base gage.



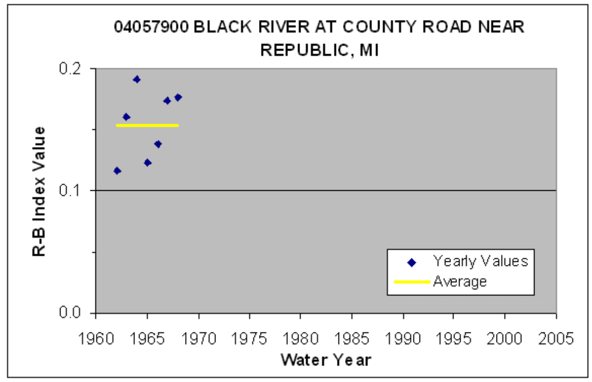
USGS Gage 04057510



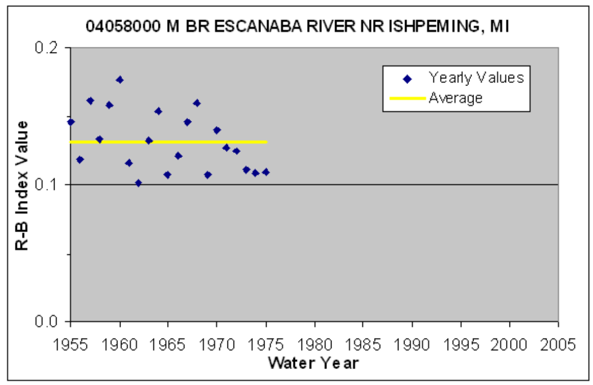
USGS Gage 04057800 – From July 1960 to June 1972 some diversions 100 feet upstream by industry for iron ore processing.



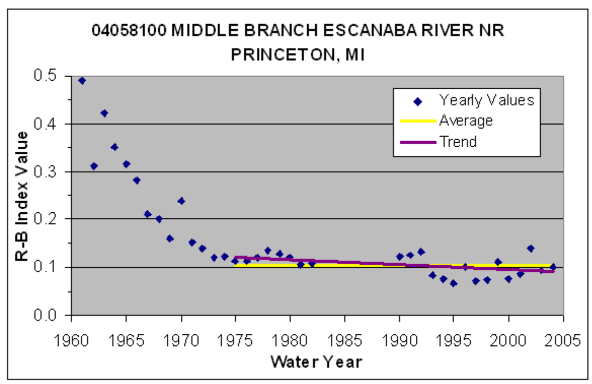
USGS Gage 04057820 – Since January 1973 flow diverted 2.3 miles upstream at Greenwood after Bay, to Green Creek for iron ore processing, some returned to middle branch Escanaba River 24 miles downstream via another Green Creek and some returned to East Branch Escanaba River via Goose Lake Outlet.



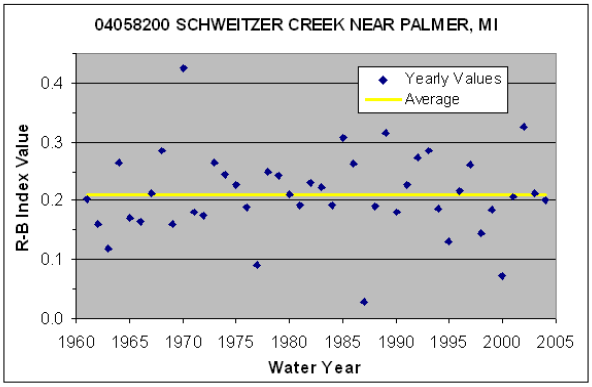
USGS Gage 04057900 – Records include effluent from industrial plant diverted into basin from Middle Branch Escanaba River.



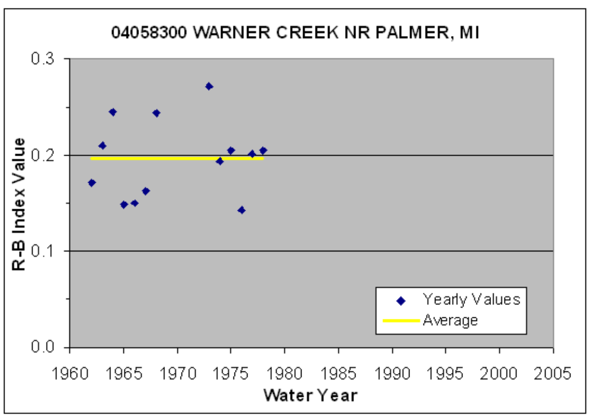
USGS Gage 04058000 – Some flow diverted and returned above station by iron ore processing plant.



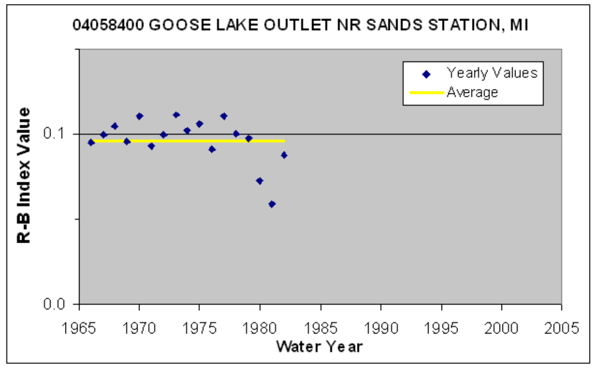
USGS Gage 04058100 – Flow regulated by power plant 400 feet upstream from station. Since December 1972 additional regulation 27 miles upstream by Greenwood release. Since January 1973 some flow diverted to Green Creek via Greenwood Diversion 27 miles upstream. October 1979 some of the diversion returned five miles downstream via Goose Lake Outlet and East Branch Escanaba River. 1973 to 1991 discharges and runoff figures were adjusted for diversion and change in contents in Greenwood reservoir.



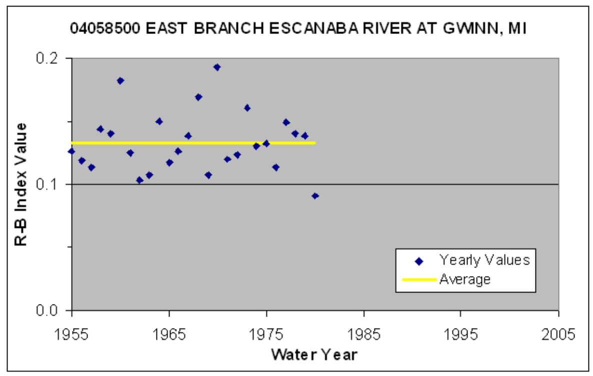
USGS Gage 04058200 – Since August 1962 flow completely regulated by Schweitzer Reservoirs one mile upstream. Prior to June 1994 some diversions from headwaters of basin for municipal supply and effluent discharge to the Carp River basin. An average of 46 cubic feet per second was diverted from Schweitzer reservoirs by industry iron ore processing, some returned via Goose Lake Outlet and East Branch Escanaba River. Diversions into Schweitzer Reservoir from Greenwood Reservoir via Greenwood diversion.



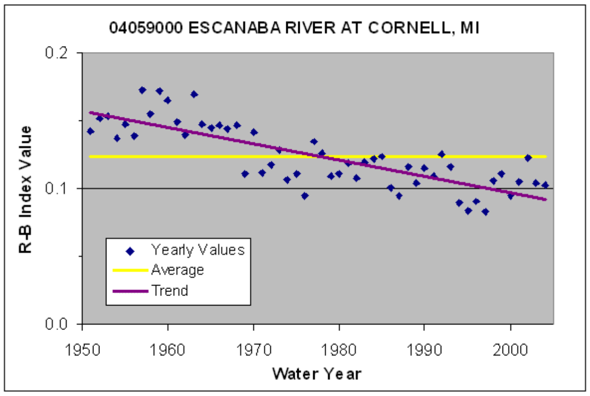
USGS Gage 04058300



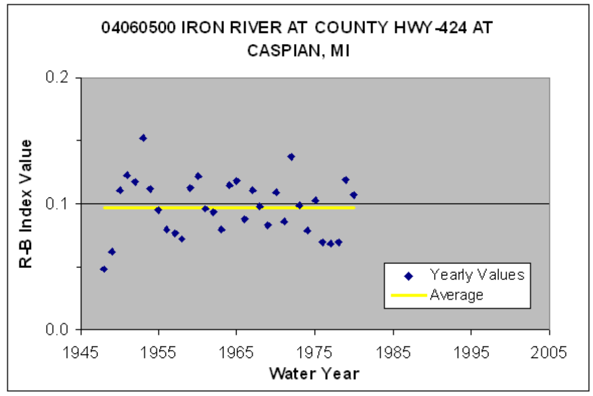
USGS Gage 04058400 – Flow includes an average of 9.6 cubic feet per second discharge into basin from mine tailings pond three miles upstream, the greater part diverted from Schweitzer Reservoir station. Diversion began October 1979.



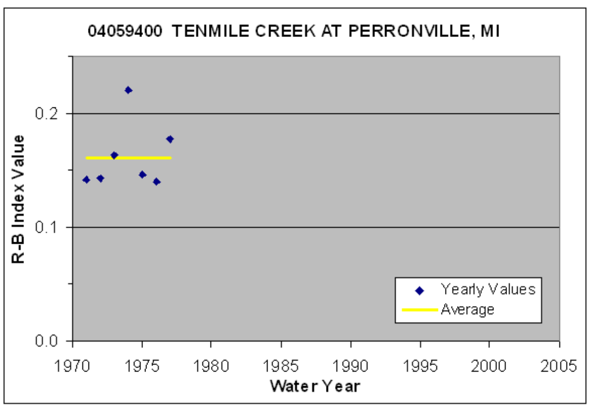
USGS Gage 04058500 – Since August 1962 some regulation by Schweitzer Reservoir about 16 miles upstream. An average of 2.2 cubic feet per second was diverted from headwaters of basin by the City of Ishpeming for municipal supply and effluent discharge to the Carp River Basin. An average of 34 cubic feet per second was diverted from Schweitzer reservoir by industry for iron ore processing, some returned to the Middle Branch Escanaba River via Green Creek and some returned to the East Branch Escanaba River via the Goose Lake Outlet. Diversion into Schweitzer Reservoir from Greenwood Reservoir via Greenwood Diversion.



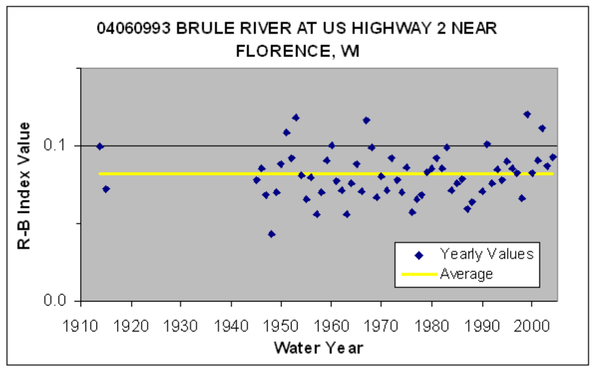
USGS Gage 04059000 – Diurnal fluctuation and occasional slight regulation caused by Boney Falls power plant seven miles above station since 1950. Since August 1962 some regulation by Schweitzer reservoir at headwaters.



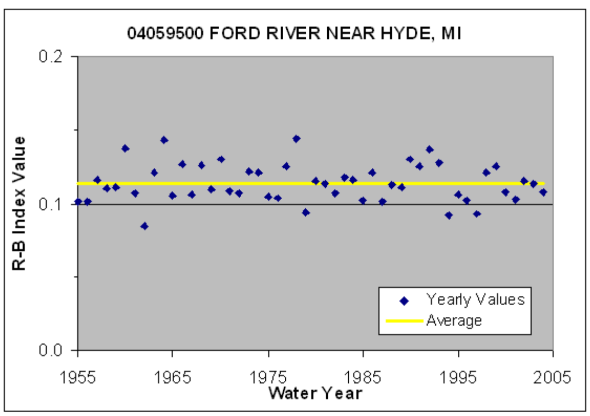
USGS Gage 04060500 – Prior to August 1978 the average flow includes mine pumpage and sewage effluent. Since August 1978 average flow includes about one foot per second sewage effluent.



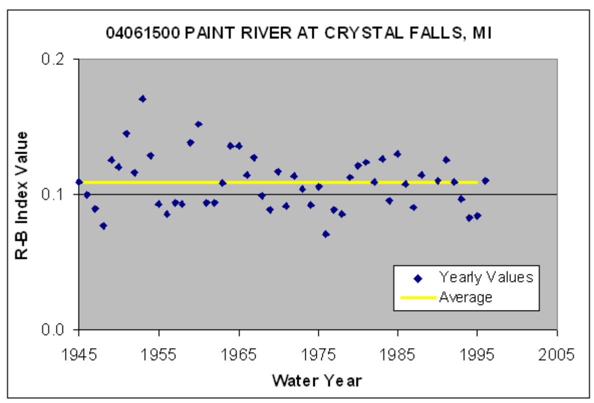
USGS Gage 04059400



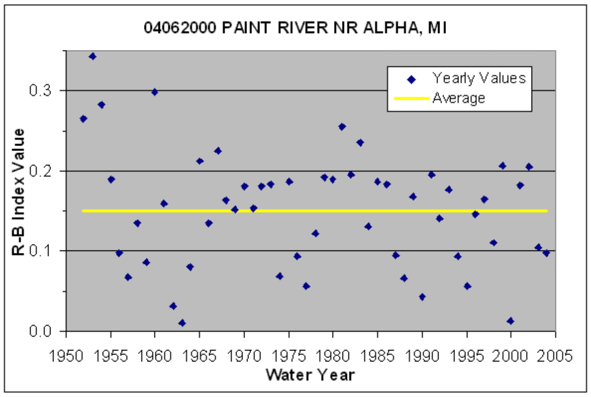
USGS Gage 04060993 – Discharge includes some mine pumpage prior to August 1977, discontinued gage 04061000 considered equivalent.



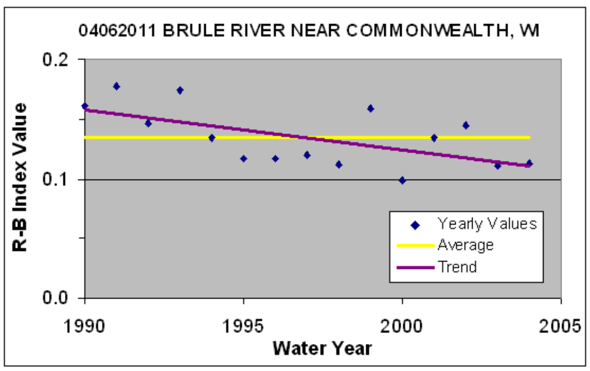
USGS Gage 04059500



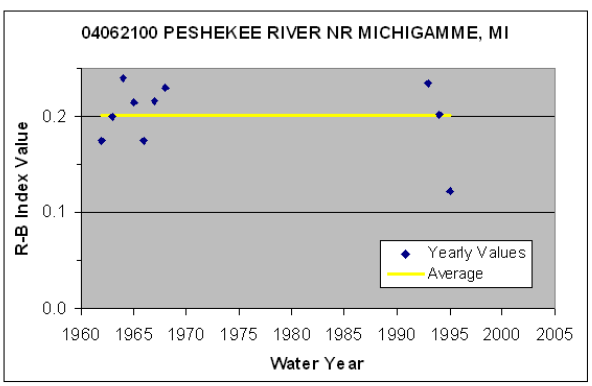
USGS Gage 04061500 – Diurnal fluctuations caused by power plant immediately upstream; since storage capacity is small, daily flows are not affected appreciably.



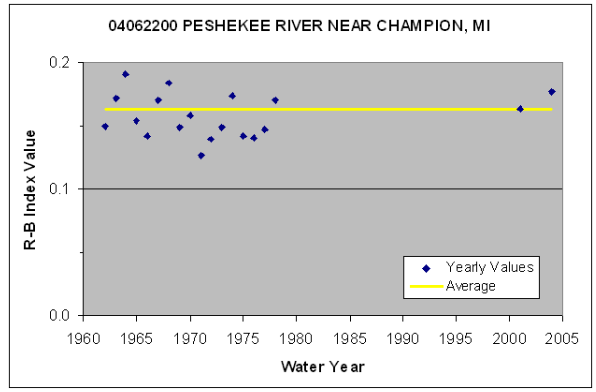
USGS Gage 04062000 – Flow completely regulated by Lower Paint Dam 0.6 miles upstream.



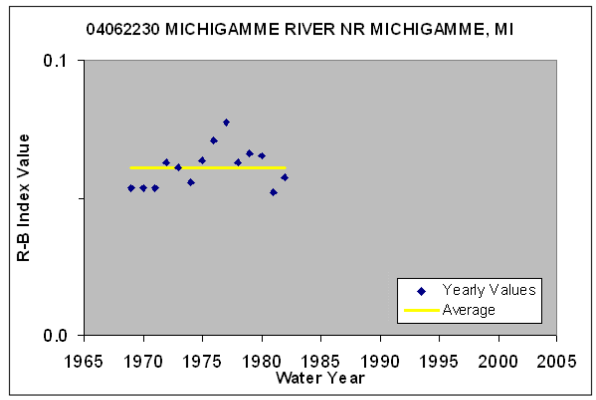
USGS Gage 04062011 – Flow regulated by power plant 900 feet upstream and by Lower Paint Dam 8.2 miles upstream.



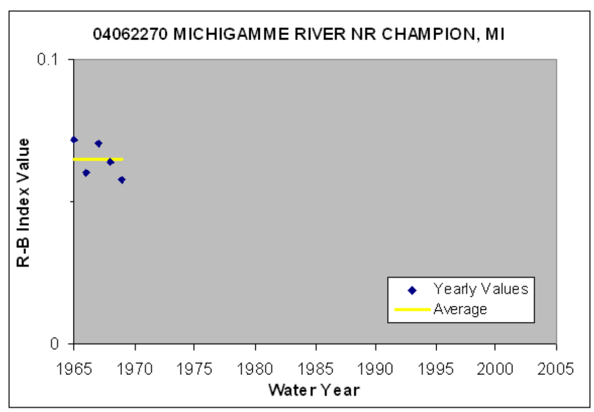
USGS Gage 04062100



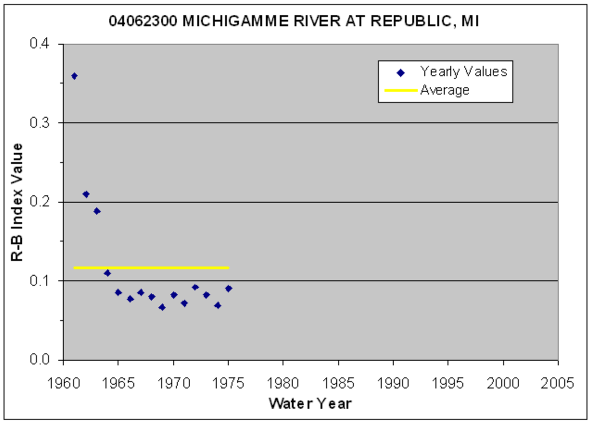
USGS Gage 04062200



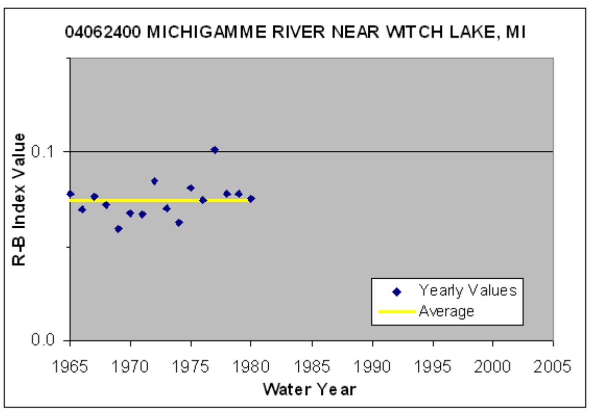
USGS Gage 04062230 – Gage may be affected by dam operations



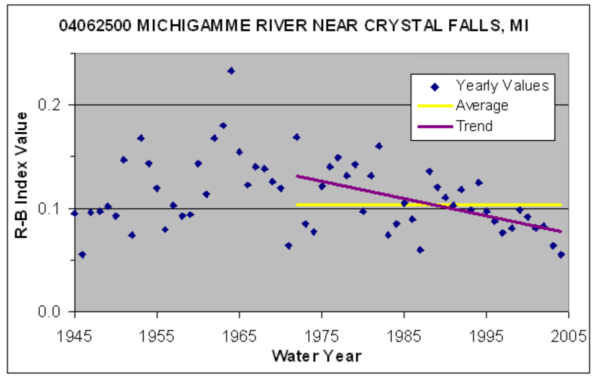
USGS Gage 04062270



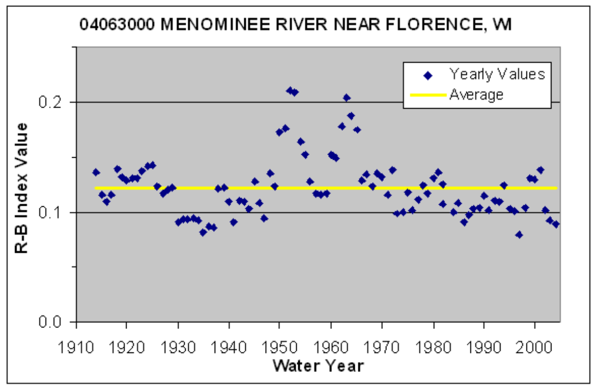
USGS Gage 04062300 – Prior to June 1, 1963 diurnal fluctuation caused by power plant 0.4 miles above station; power plant abandoned and only occasional regulation since. Since June 1, 1963 water diverted 0.5 miles above station for industrial use and returned to river by Gambles Creek five miles downstream.



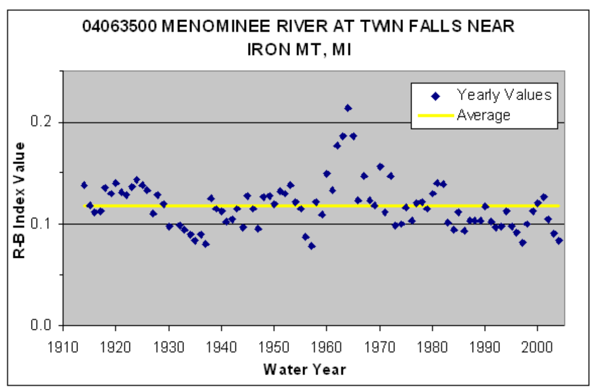
USGS Gage 04062400 – Water discharge records good except those from the winter period, which are fair. Occasional regulation 14 miles upstream. Some flow diverted and returned to the above station by an iron ore processing plant.



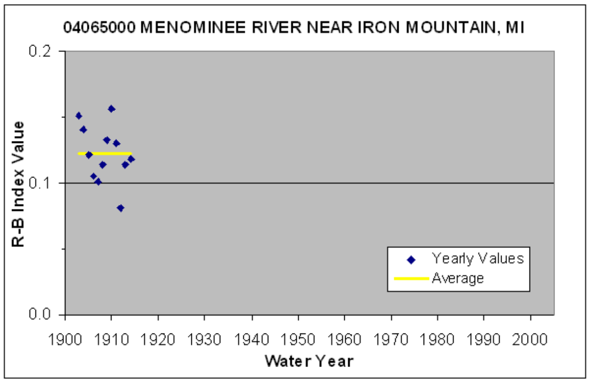
USGS Gage 04062500 – Regulated by power plant and Michigan reservoir five miles upstream.



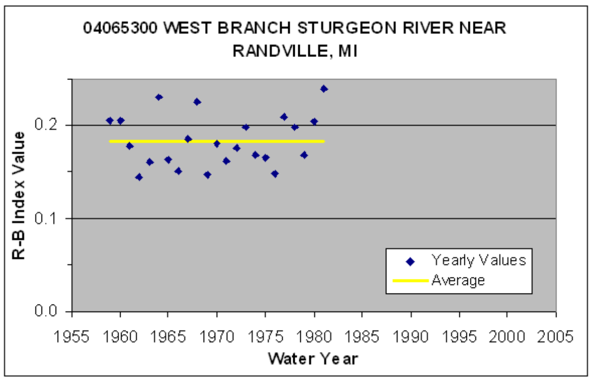
USGS Gage 04063000 – Prior to July 1950 discharge determined from power plant records, flow regulated by power plants, Michigamme Reservoir, Peavy Pond, and many smaller reservoirs upstream from station.



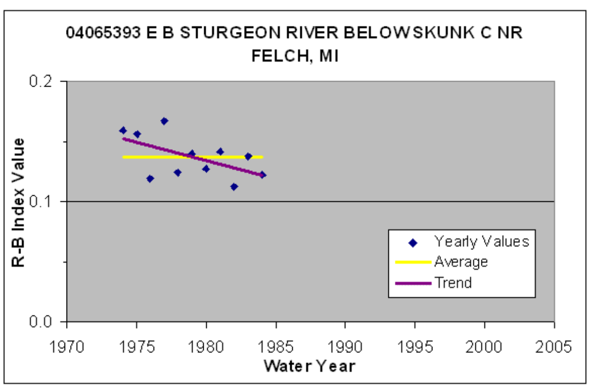
USGS Gage 04063500 – Prior to 1957 discharge determined from power plant records. Flow regulated by power plants, Michigamme Reservoir, Peavy Pond, and many smaller reservoirs upstream from station.



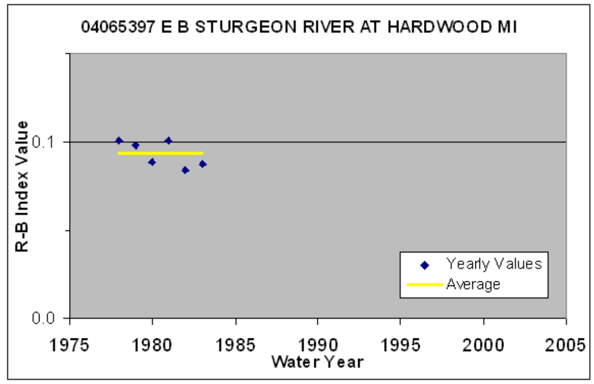
USGS Gage 04065000



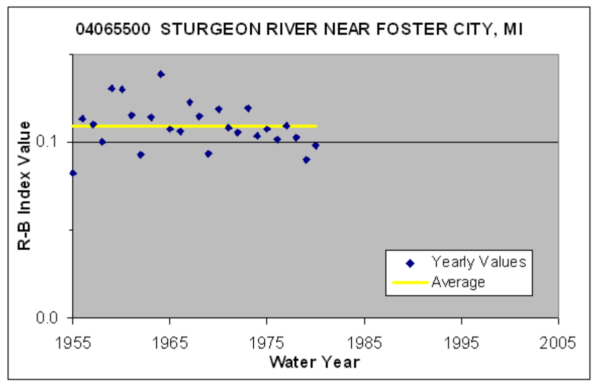
USGS Gage 04065300 – Since December 1958 diversion above for industrial use; figures of runoff adjusted thereafter. Small diversions for sprinkler irrigation.



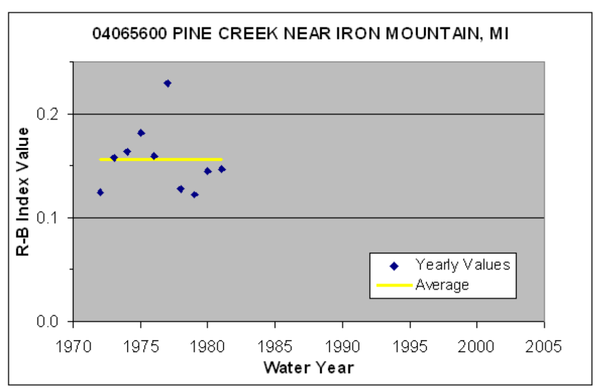
USGS Gage 04065393 – Since June 1975 occasional regulation during low flows by Gene Lake Reservoir three miles upstream.



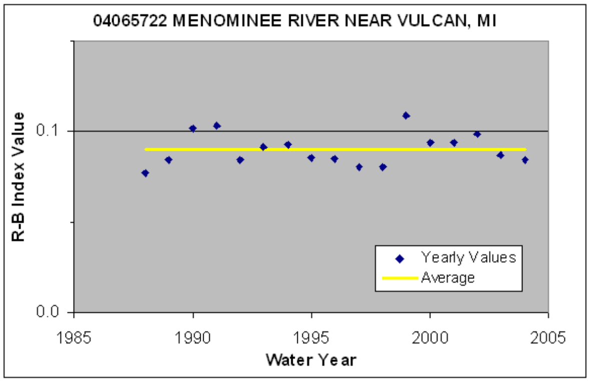
USGS Gage 04065397 – Occasional regulation during low flows by Gene Lake Reservoir in headwater and hardwood reservoir 1.2 miles upstream.



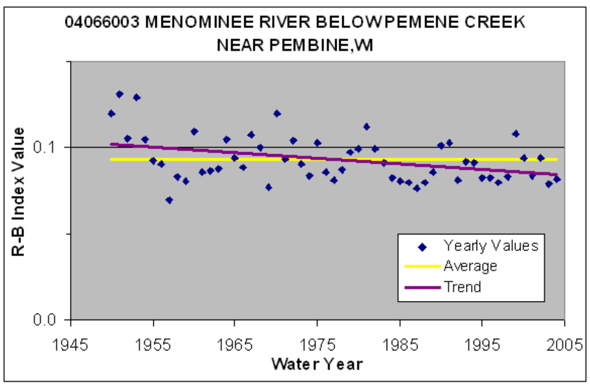
USGS Gage 04065500 – Since December 1958 diversion above station for industrial use; figures of runoff adjusted thereafter. Since June 1975 occasional regulation during low flows by reservoirs in headwaters from East Branch. Small diversions for sprinkler irrigation.



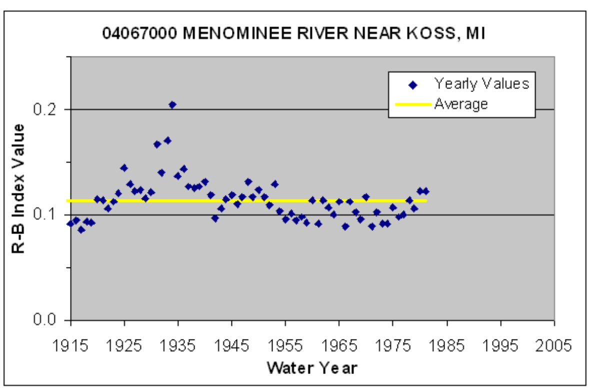
USGS Gage 04065600 – Flow includes an average of 5.6 cubic feet per second diverted from West Branch Sturgeon River basin.



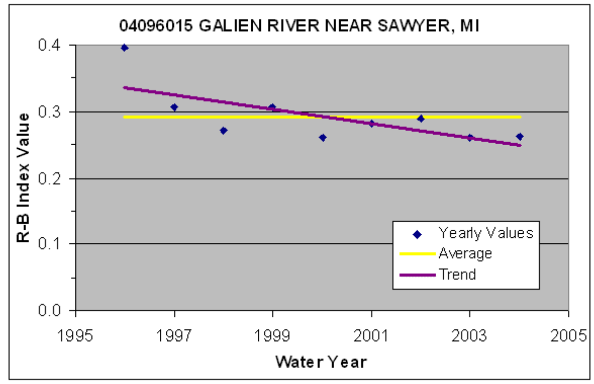
USGS Gage 04065722 – Flow regulated by power plants, Michigamme Reservoir, Peavy Pond, and many smaller reservoirs upstream from station.



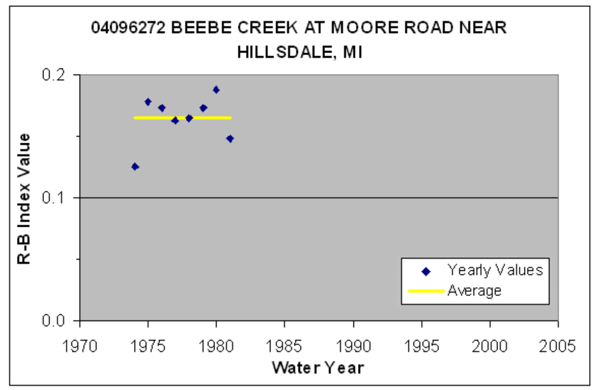
USGS Gage 04066003 – Flow regulated by power plants, Michigamme Reservoir, Peavy Pond, and many smaller reservoirs upstream from station.



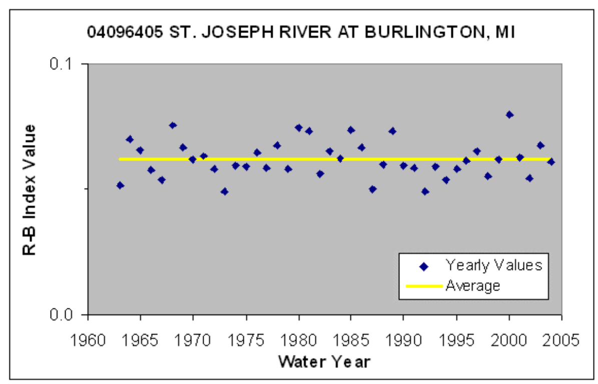
USGS Gage 04067000 – Flow regulated by power plants, Michigamme Reservoir, Peavy Pond on Michigamme River, and by smaller reservoirs above station.



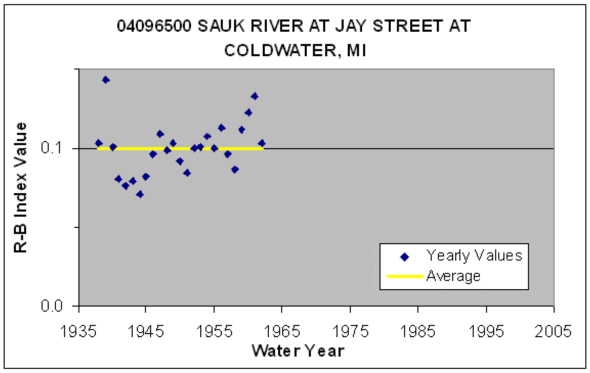
USGS Gage 04096015



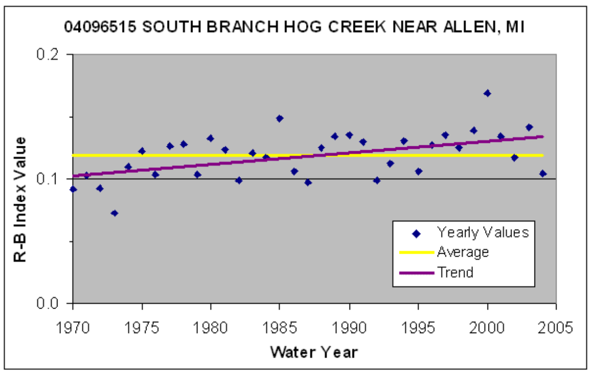
USGS Gage 04096272 – Occasional regulation by Lake Belair about five miles above location.



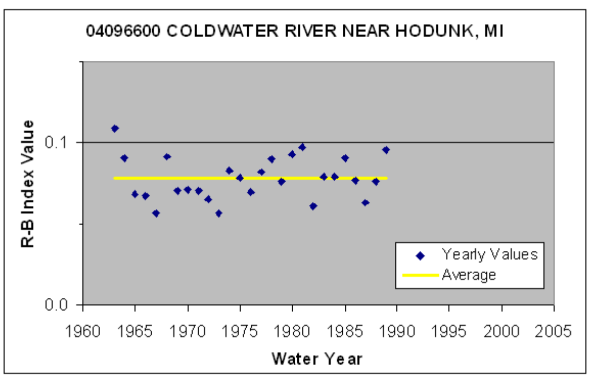
USGS Gage 04096405 – Discontinued gage 04096400 considered equivalent.



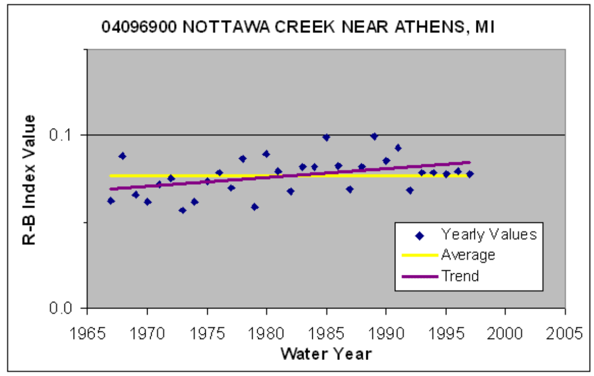
USGS Gage 04096500 – Drainage area indeterminate due to infrequent contribution to or from Coldwater Lake. Regulation caused by dam at outlet of Marble Lake.



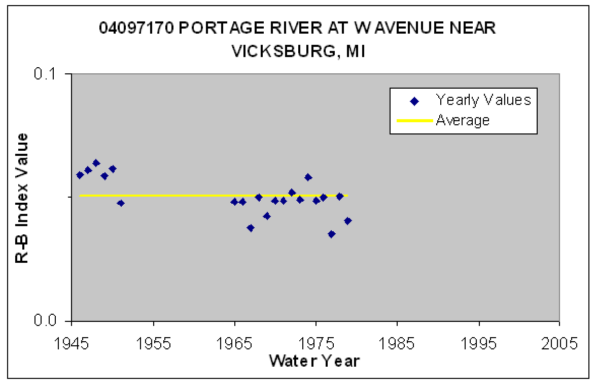
USGS Gage 04096515



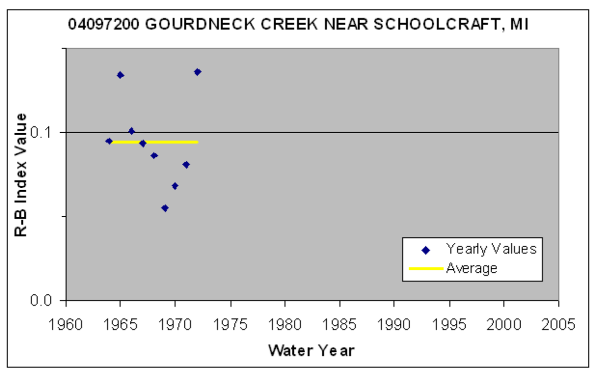
USGS Gage 04096600 – Diurnal fluctuation caused by mills upstream above station.



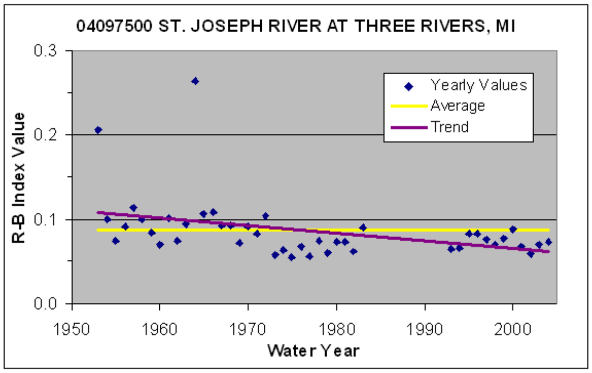
USGS Gage 04096900



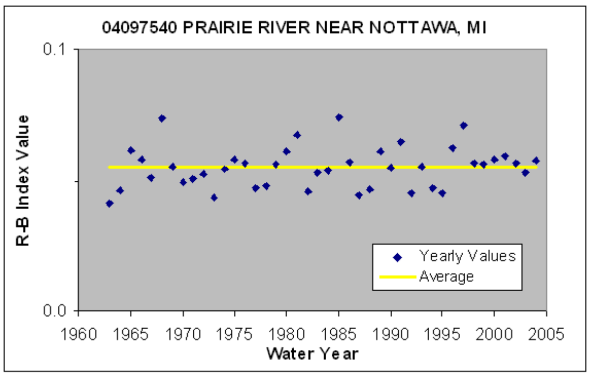
USGS Gage 04097170



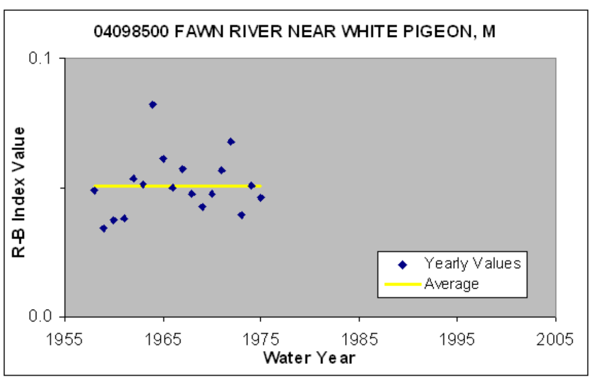
USGS Gage 04097200 – Gourdneck canal diverts water from stream 100 feet above station to sustain lake levels.



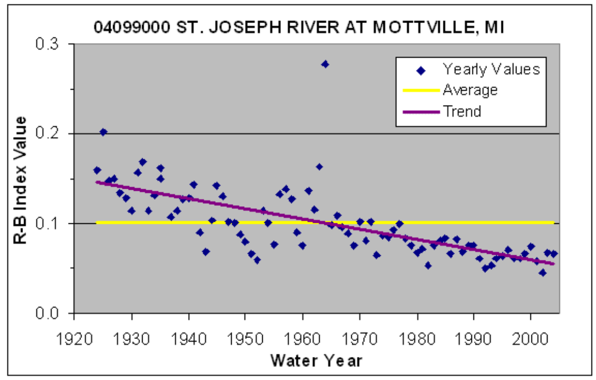
USGS Gage 04097500 – Flow regulated by power plant upstream from station.



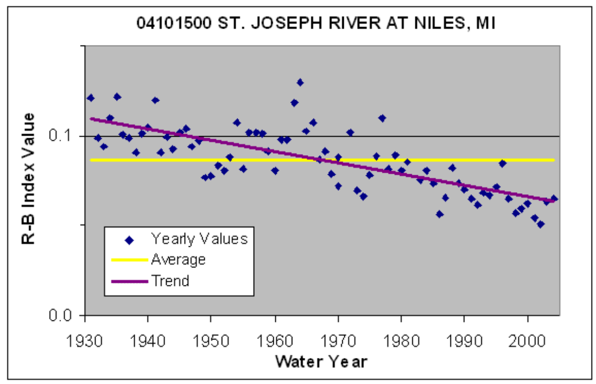
USGS Gage 04097540 – Since 1987 some diversion by pumping for sprinkler irrigation.



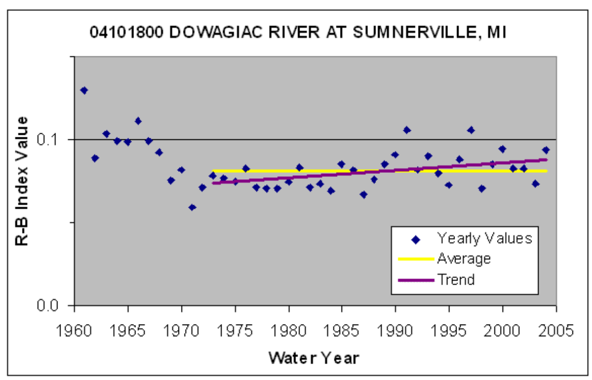
USGS Gage 04098500 – Small diurnal fluctuation caused by power plants above station.



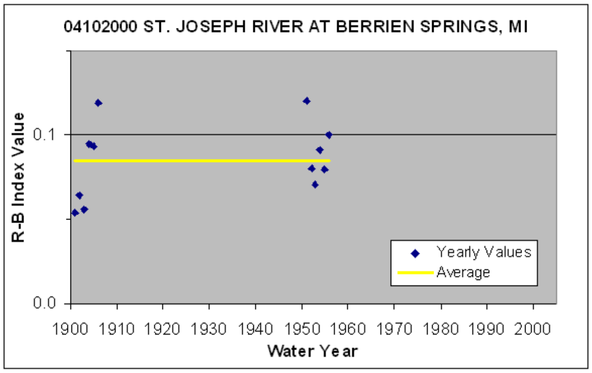
USGS Gage 04099000 – Flow regulated by power plants upstream from station.



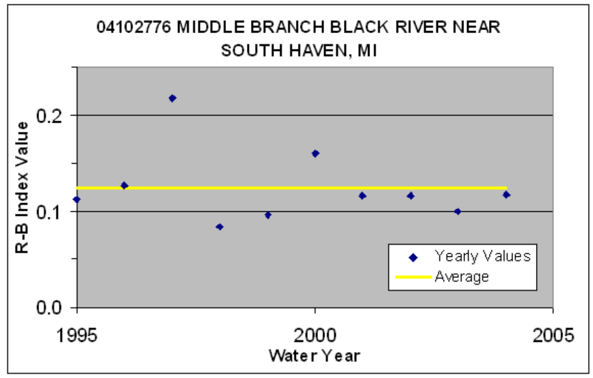
USGS Gage 04101500 – Flow regulated by power plants upstream from station.



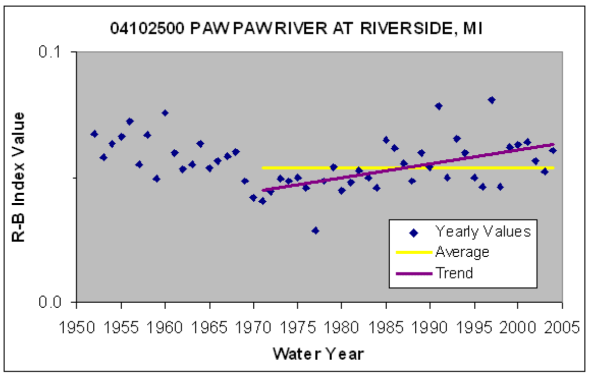
USGS Gage 04101800 – Flow regulated by millpond and lake-level control dam upstream from station.



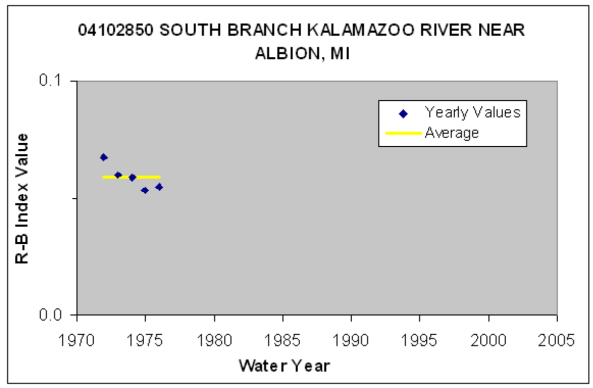
USGS Gage 04102000



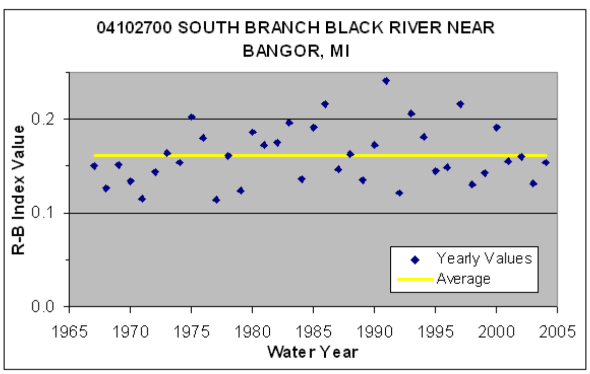
USGS Gage 04102776



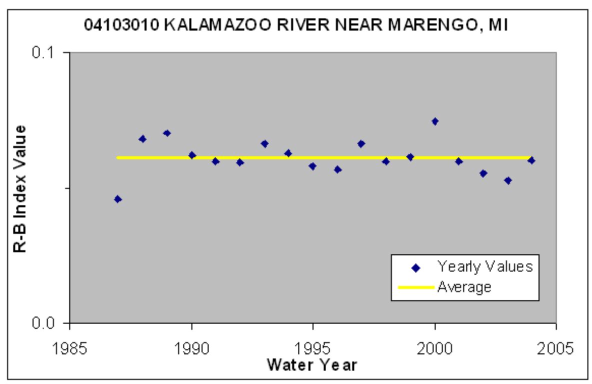
USGS Gage 04102500 – Diurnal fluctuation, principally during low flow, caused by paper mill upstream from station.



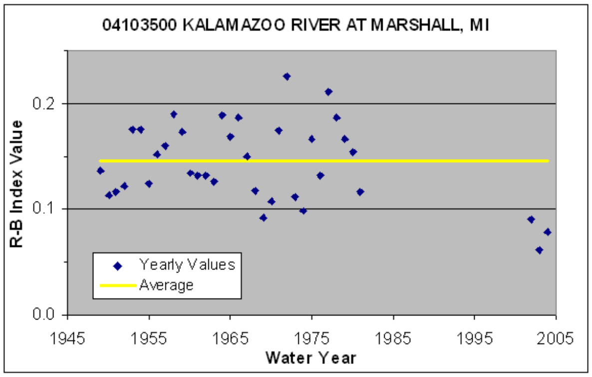
USGS Gage 04102850



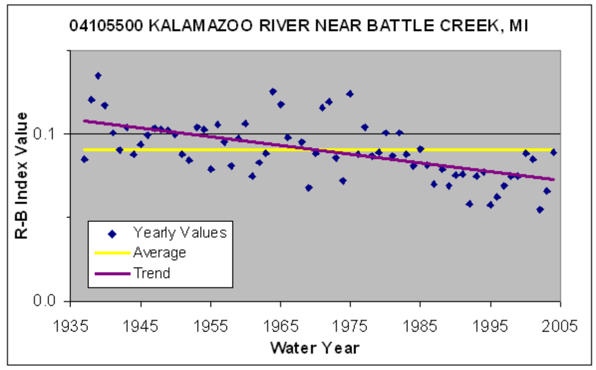
USGS Gage 04102700 – Occasional regulation caused by mills upstream from station.



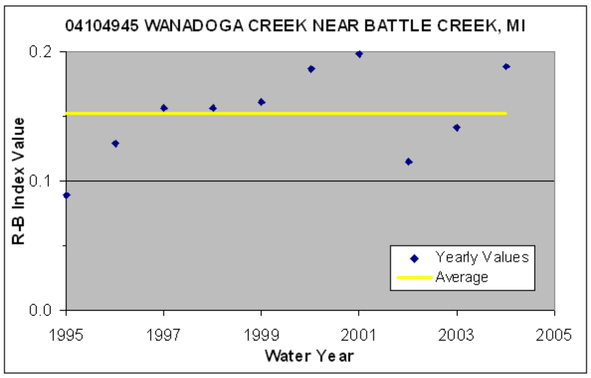
USGS Gage 04103010 – Some diversion by pumping for irrigation.



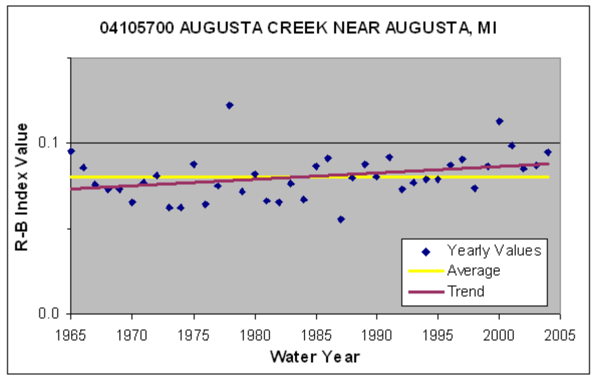
USGS Gage 04103500 – Flow regulated by power plant upstream from station.



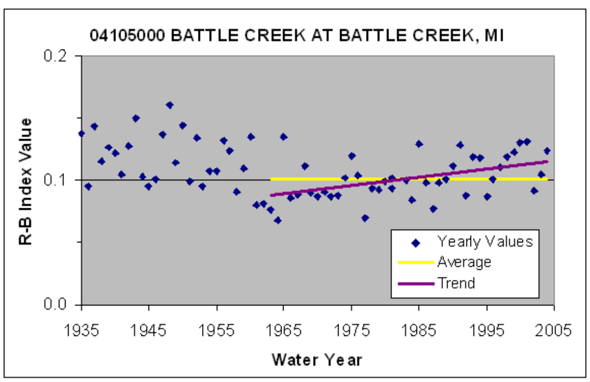
USGS Gage 04105500 – Diurnal fluctuation below 1500 feet per second caused by power plants upstream from station.



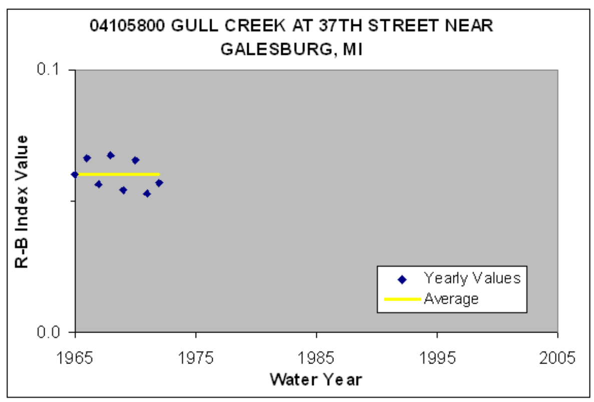
USGS Gage 04104945



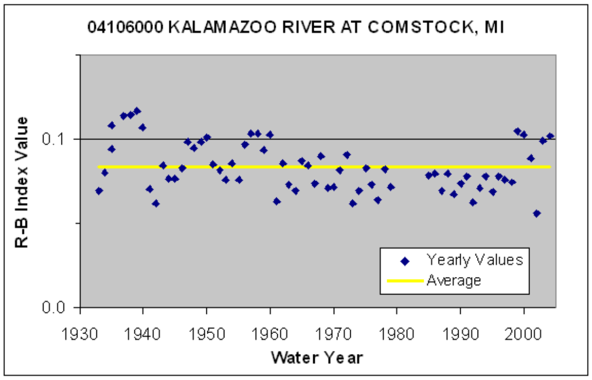
USGS Gage 04105700



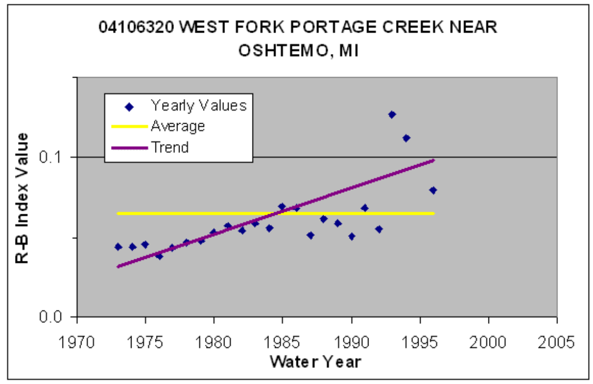
USGS Gage 04105000 – Occasional slight regulation prior November 1943.



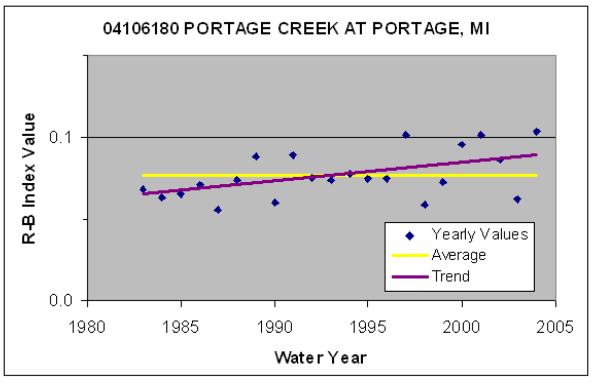
USGS Gage 04105800 – Occasional regulation by many dams upstream.



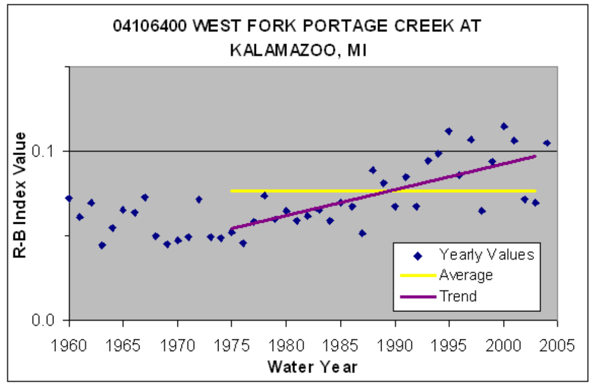
USGS Gage 04106000 – Flow regulation by power plant 1.2 miles upstream from station.



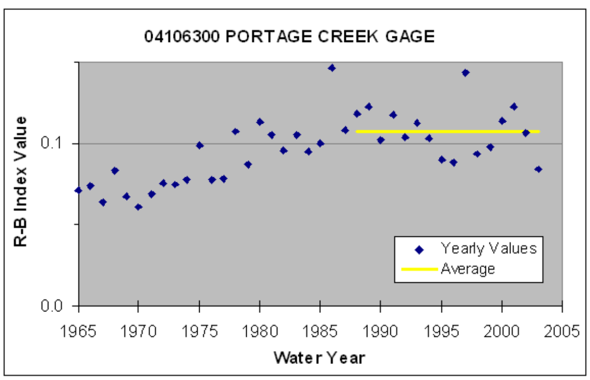
USGS Gage 04106320 – At times flow is affected by ground water withdrawals.



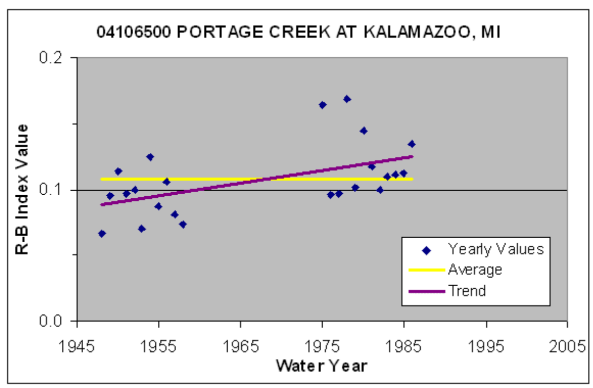
USGS Gage 04106180



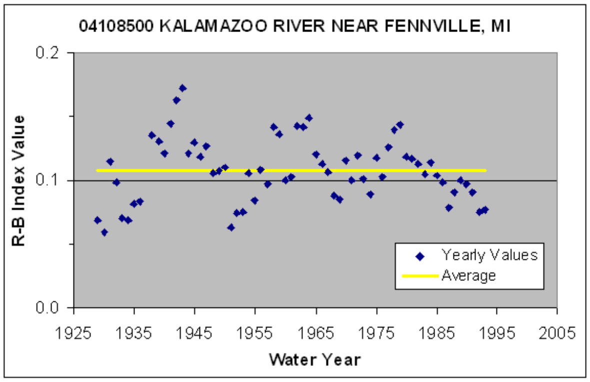
USGS Gage 04106400 – At times water is affected by water withdrawals.



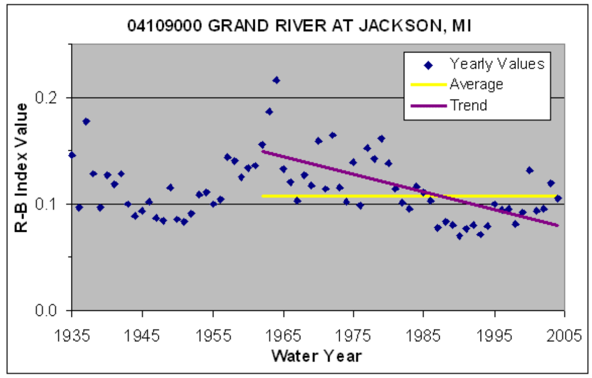
USGS Gage 04106300 – Flow includes water which is pumped from ground water sources by industry and discharge into stream two miles upstream from station.



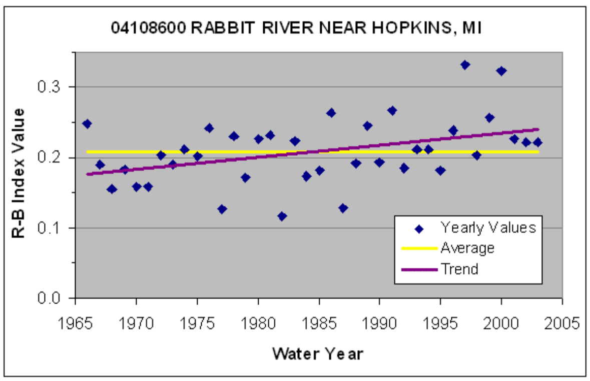
USGS Gage 04106500 – Some regulation by mill ponds upstream from station. Flow includes water which is pumped from groundwater sources by industry and discharged into stream five miles upstream from station.



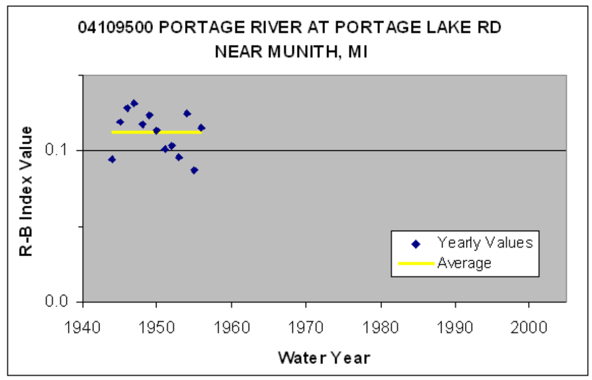
USGS Gage 04108500 – Flow regulated at low and medium flow stages by power plant upstream from station and since June 1936 by Calkins Dam and power plant four miles up stream.



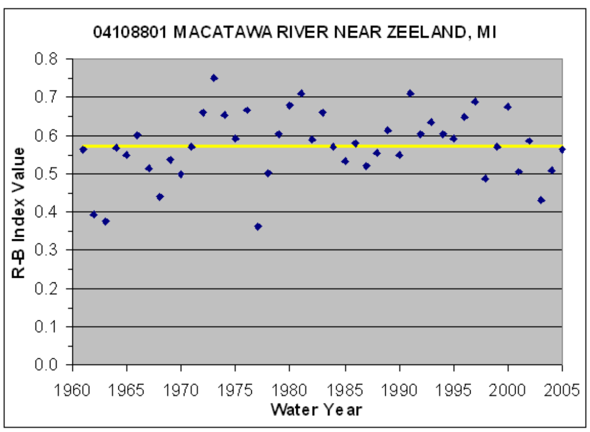
USGS Gage 04109000 – Slight regulation by mill upstream, flow includes 20 cubic feet per second as sewage effluent which originates from ground water sources from the City of Jackson.



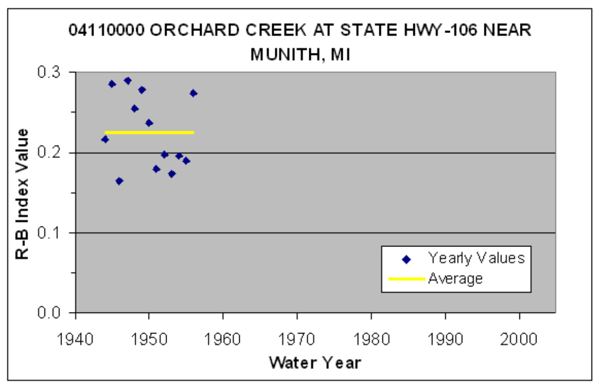
USGS Gage 04108600



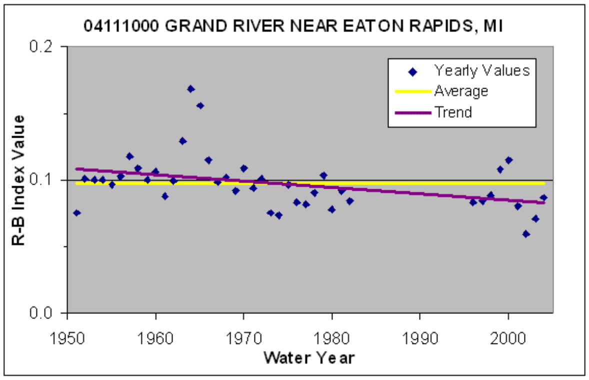
USGS Gage 04109500



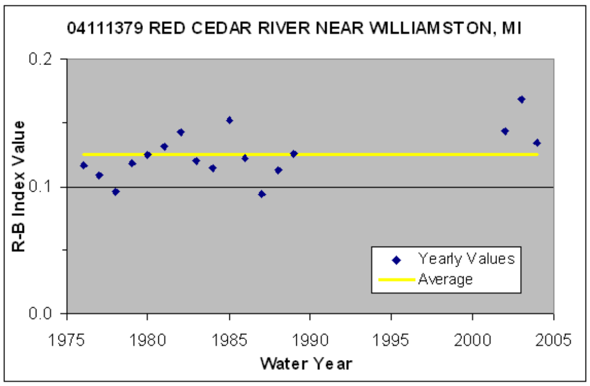
USGS Gage 04108801 – Prior to October 1978 published as Black River near Zeeland.



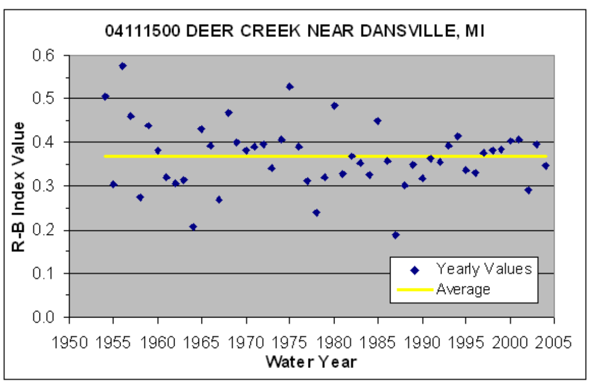
USGS Gage 04110000



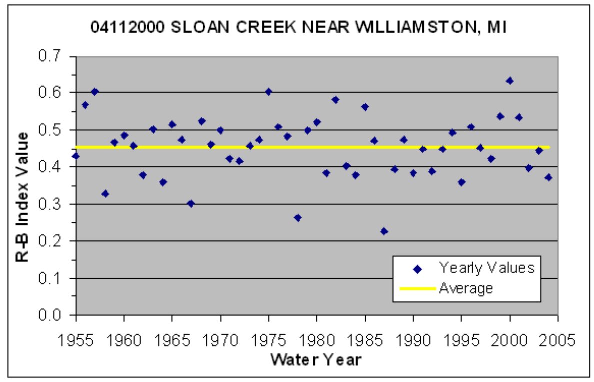
USGS Gage 04111000 – Flow regulated by Smithville Dam and mills at Eaton Rapids.



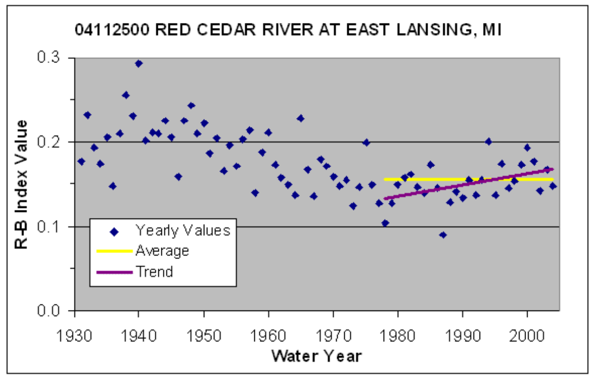
USGS Gage 04111379 – Flow is regulated at times by pumpage for irrigation.



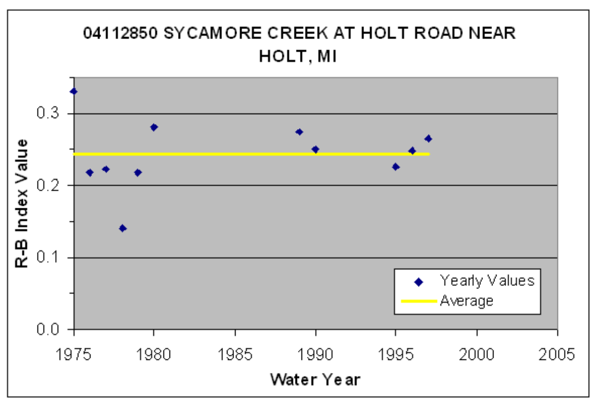
USGS Gage 04111500



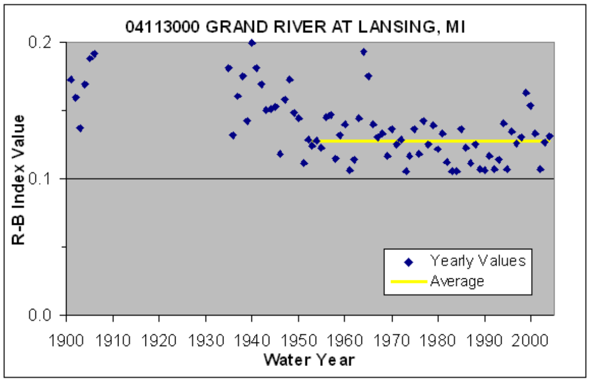
USGS Gage 04112000 – At times flow is regulated by pumpage from irrigation.



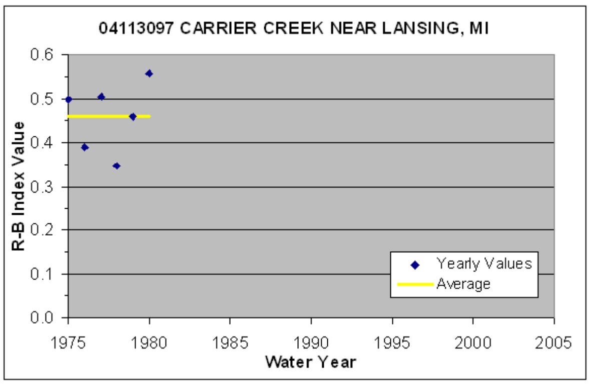
USGS Gage 04112500 – Prior to 1975 occasional regulation at low flow by mill at Williamston, 16 miles upstream.



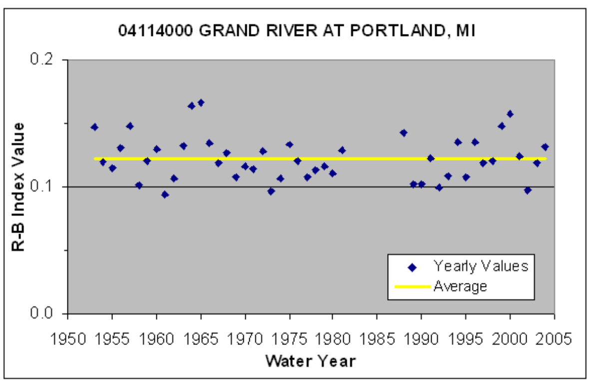
USGS Gage 04112850



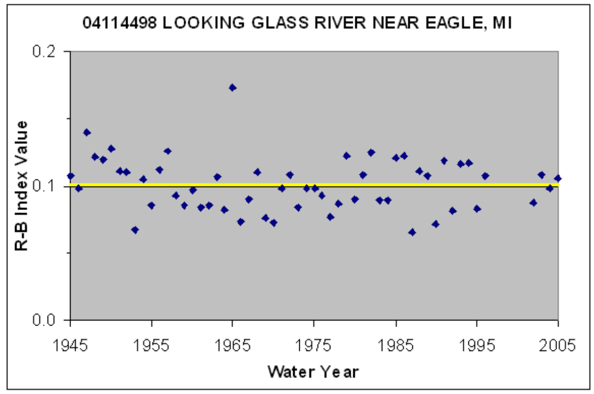
USGS Gage 04113000 – Large diurnal fluctuation at low flow and medium flow caused by power plants upstream from station.



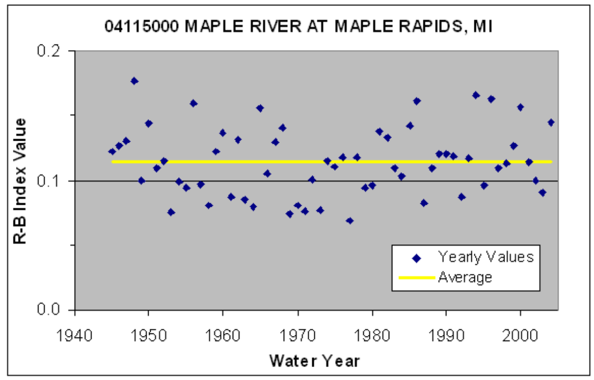
USGS Gage 04113097



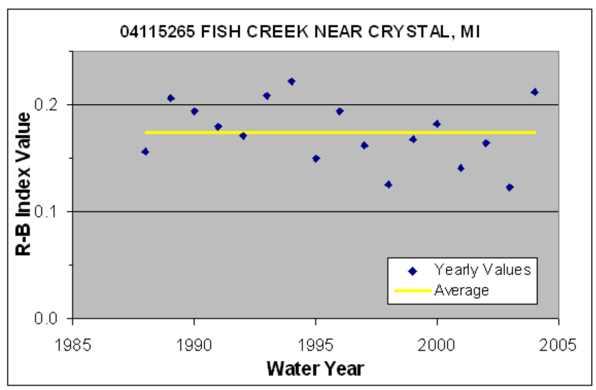
USGS Gage 04114000 – Slight diurnal fluctuation caused by power plants upstream from station.



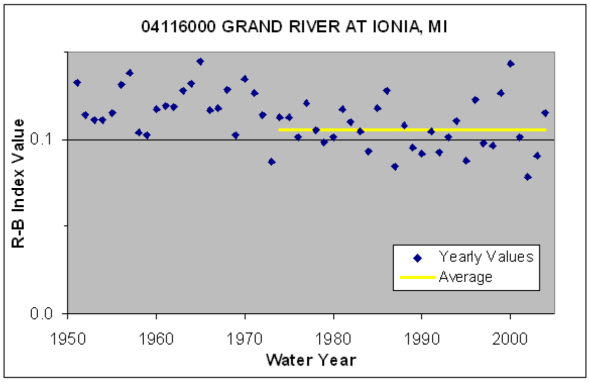
USGS Gage 04114498 – Small intermittent diversions at times into Lake Geneva when discharge is above fifty cubic feet per second.



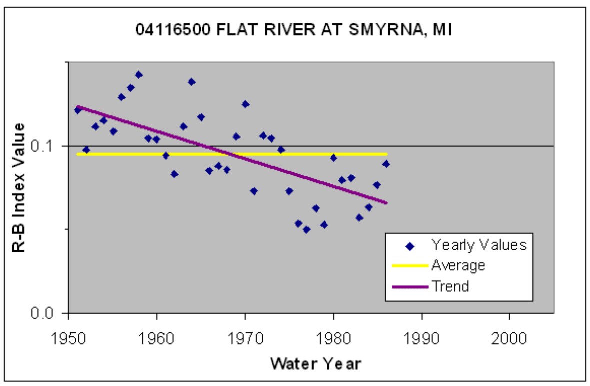
USGS Gage 04115000 – At times water is pumped from the river about eight miles upstream to fill the wetlands in the Maple River State Game Area. Some of the water is returned to the river at a later date, when the water levels are lowered.



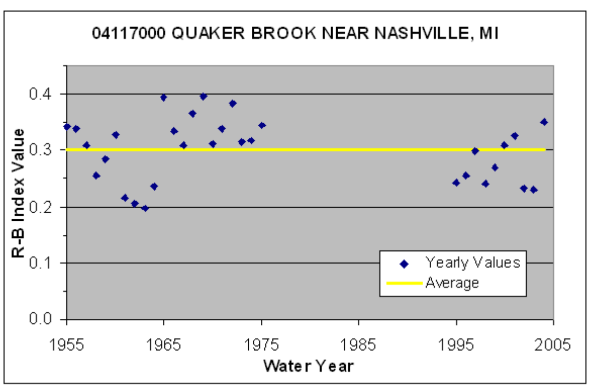
USGS Gage 04115265 – At times low flow is affected by pumpage for irrigation.



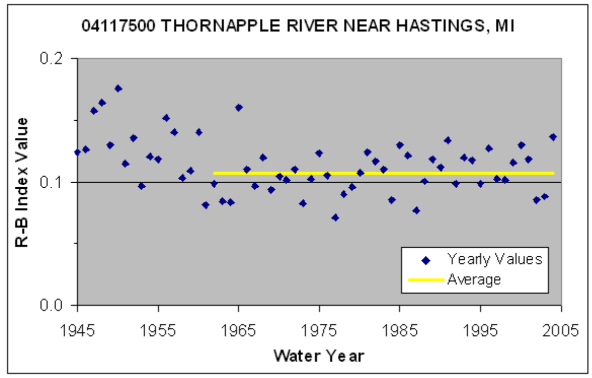
USGS Gage 04116000 – Diurnal fluctuation below approximately 5,000 cubic feet per second caused by power plants upstream from station.



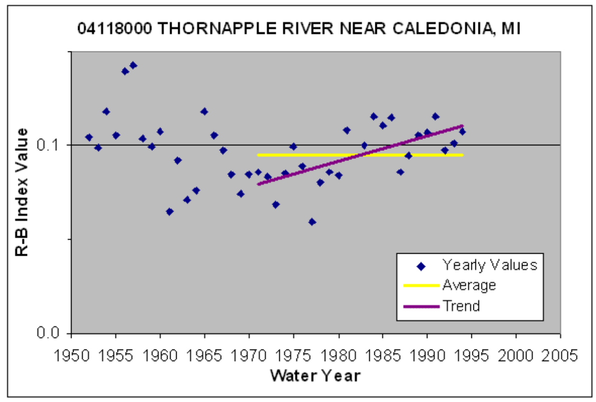
USGS Gage 04116500 – Diurnal fluctuation caused by power plants above station prior to September 1956; occasional diurnal fluctuation since.



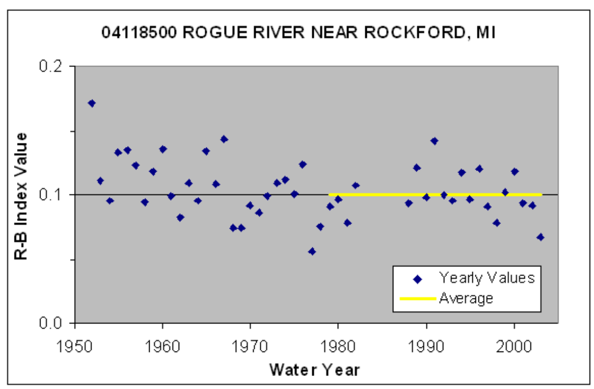
USGS Gage 04117000



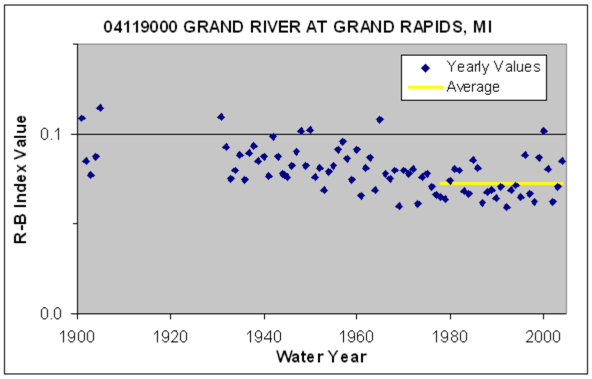
USGS Gage 04117500



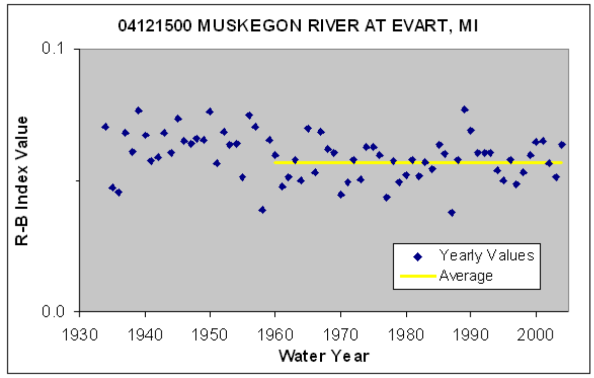
USGS Gage 04118000 – Prior to December 1958 and since October 1983 large diurnal fluctuation at low and medium flow and occasional regulation during high flow, caused by power plant upstream from station; occasional fluctuation during the interim period.



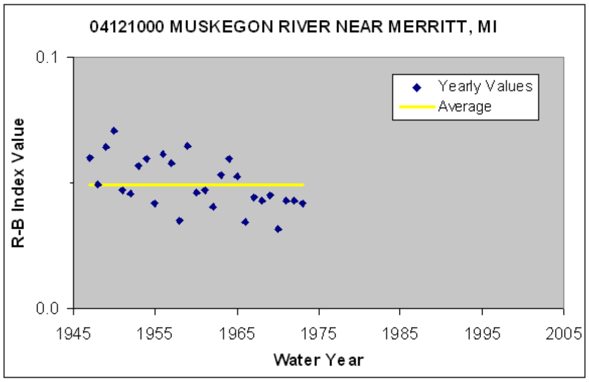
USGS Gage 04118500 – Some regulation caused by dam two miles upstream from station.



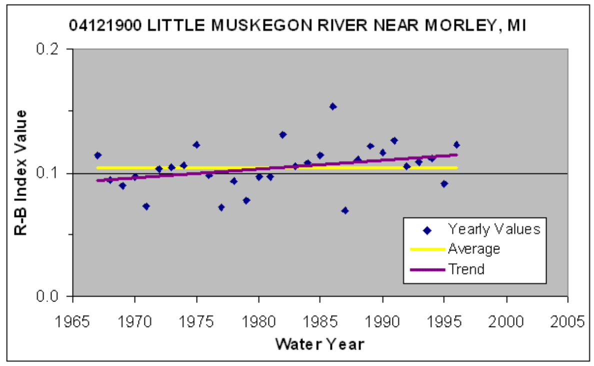
USGS Gage 04119000 – Moderate diurnal fluctuation at low and medium flow caused by power plants upstream from station.



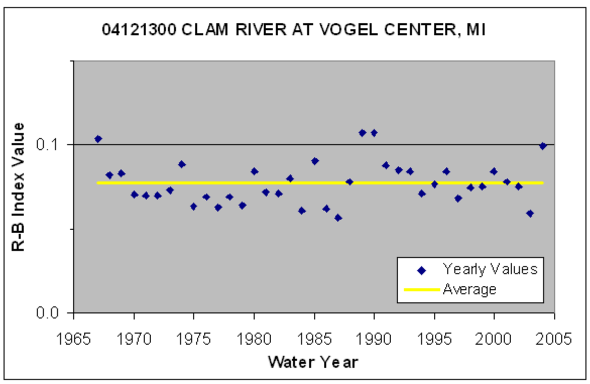
USGS Gage 04121500 – Some regulation at low flow by dams upstream from station.



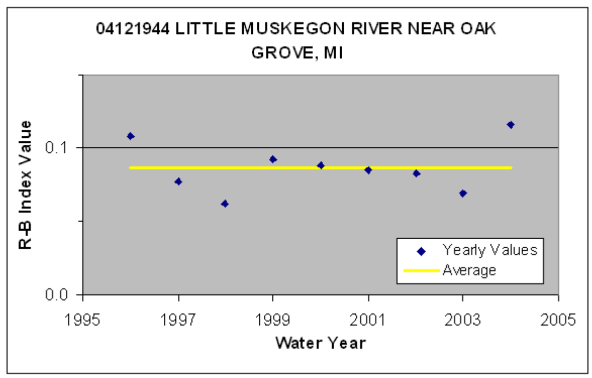
USGS Gage 04121000 – Occasional regulation by manipulation of stop logs at Reedsburg Dam.



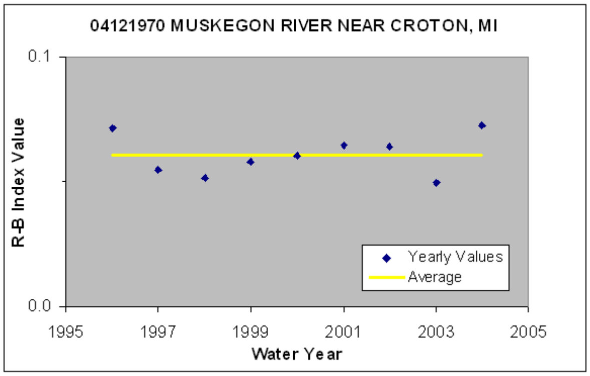
USGS Gage 04121900 – Some regulation by dam above station.



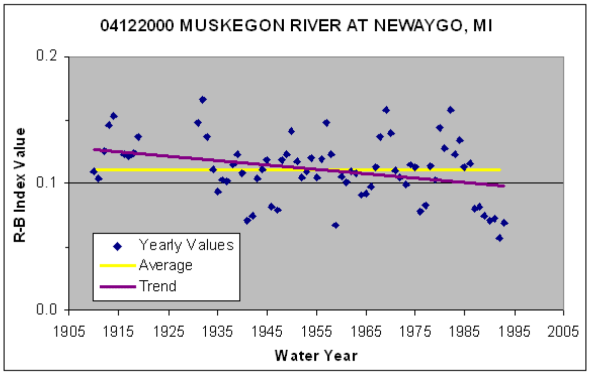
USGS Gage 04121300 – Some regulation at low flow by dams upstream from station.



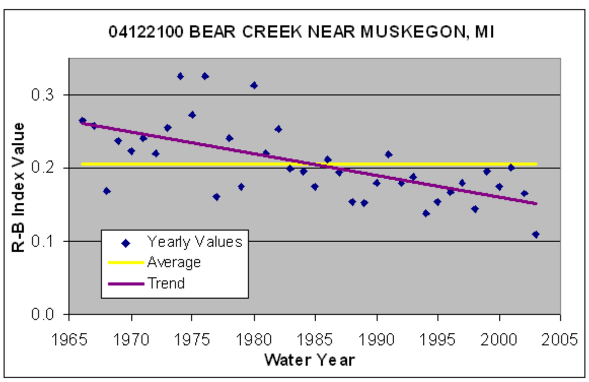
USGS Gage 04121944



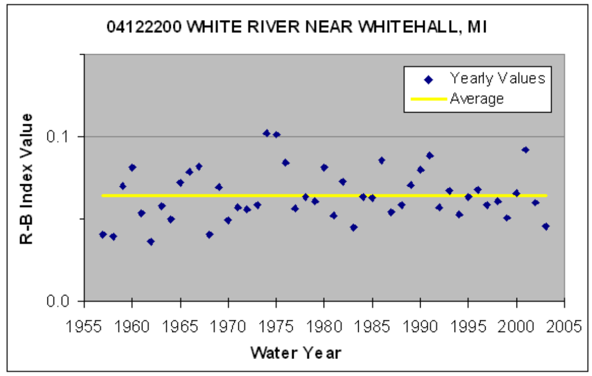
USGS Gage 04121970 – Flow completely regulated by Croton Dam 1,000 feet upstream.



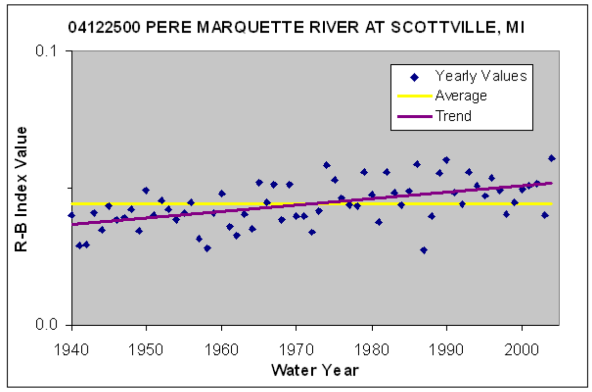
USGS Gage 04122000 – Flow regulated by power plants upstream from station, the largest of which are Croton Dam, Hardy Dam, and Rogers Dam. Since December 27, 1965 power plant at Newaygo is non-operative. In January 1969, dam at Newaygo was removed.



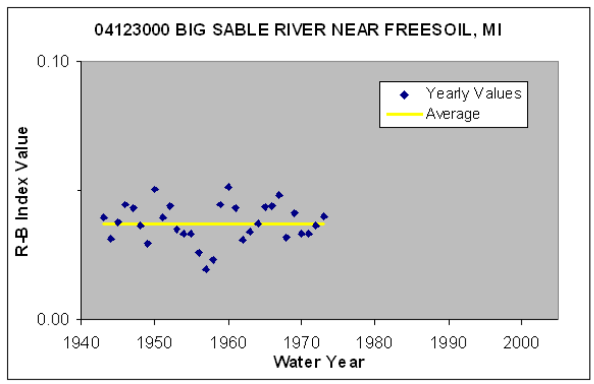
USGS Gage 04122100 – Some regulation during low flow by dams and irrigation upstream from station.



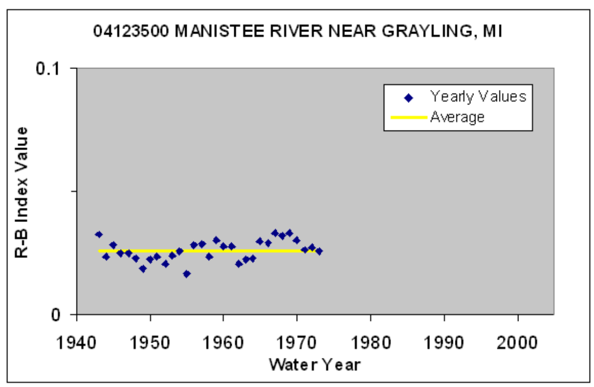
USGS Gage 04122200



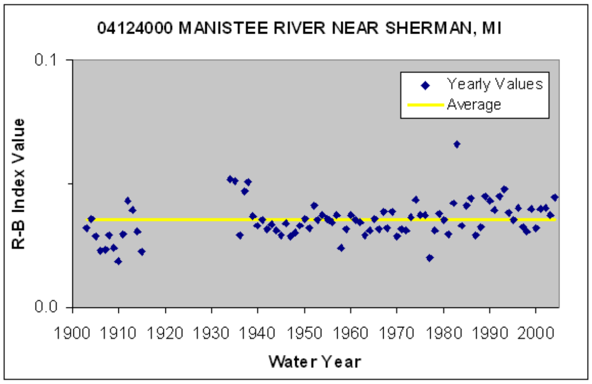
USGS Gage 04122500



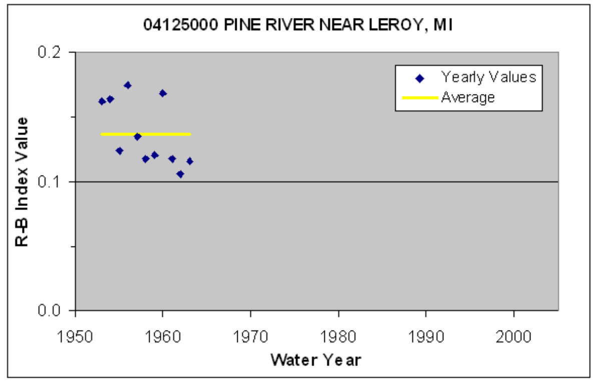
USGS Gage 04123000



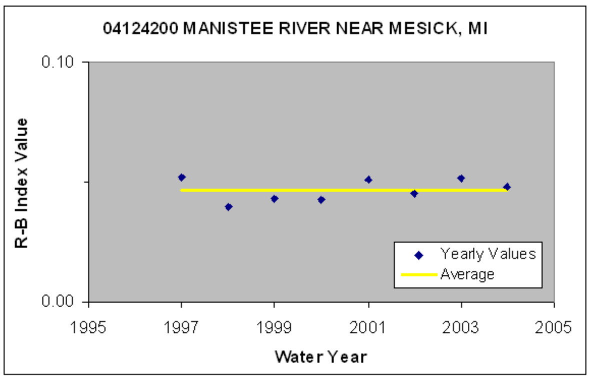
USGS Gage 04123500



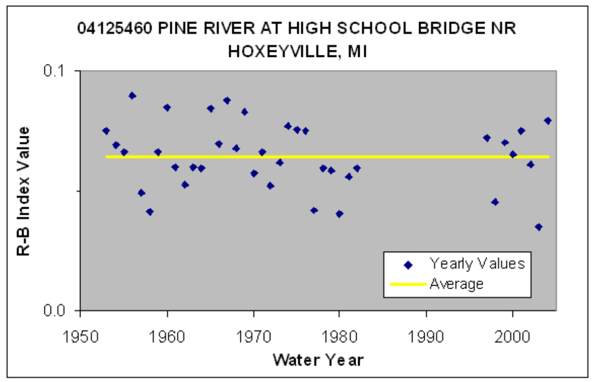
USGS Gage 04124000



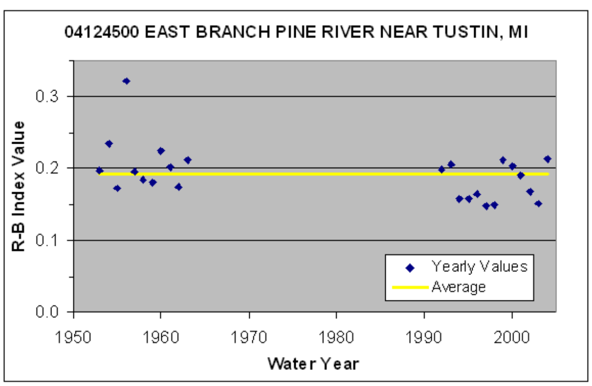
USGS Gage 04125000



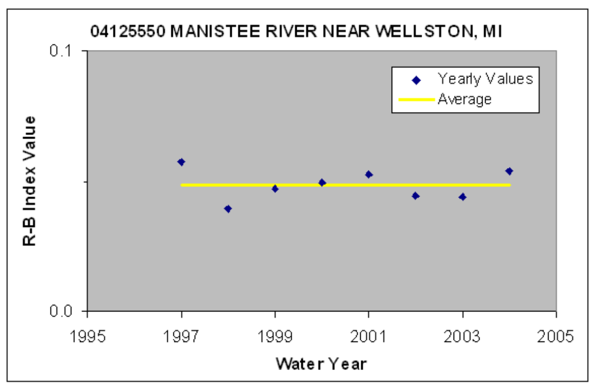
USGS Gage 04124200 – Flow completely regulated by Hodenpyl Dam 200 feet upstream.



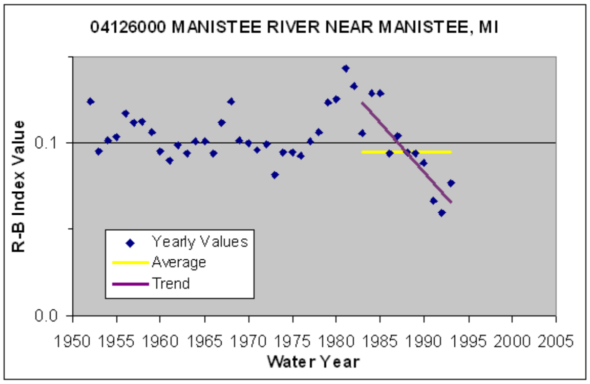
USGS Gage 04125460 – Discontinued gage 04125500 considered equivalent.



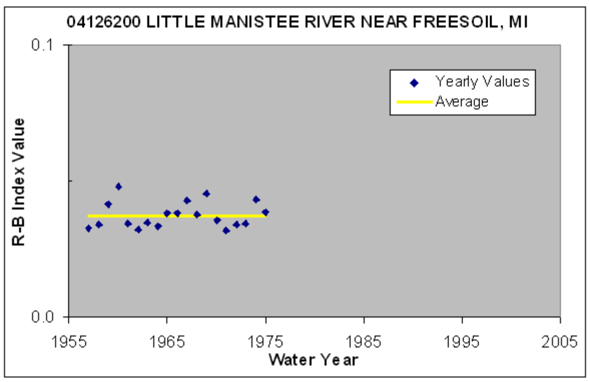
USGS Gage 04124500



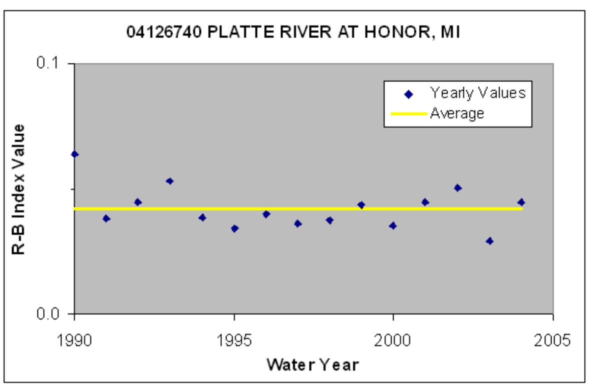
USGS Gage 04125550 – Flow completely regulated by Tippy Dam 700 feet upstream



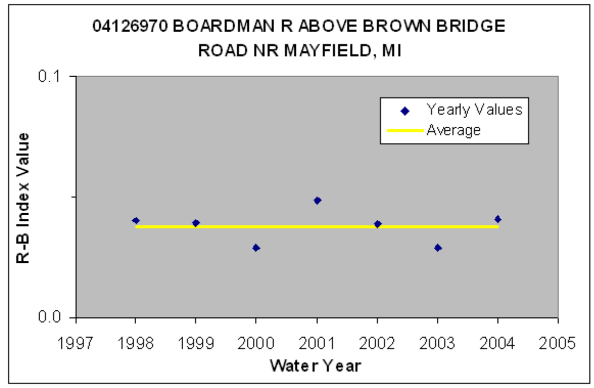
USGS Gage 04126000 – Flow regulated at all stages by Tippy Hydroelectric Power Plant 21 miles upstream.



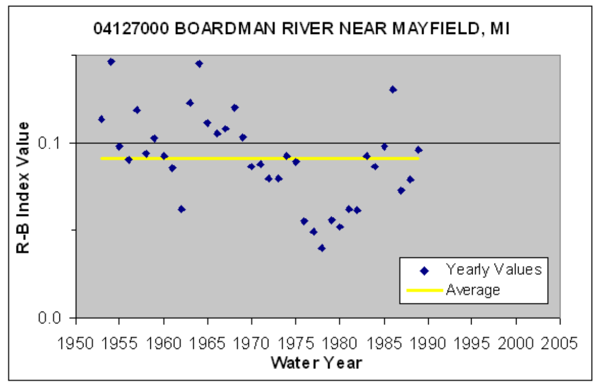
USGS Gage 04126200 – Some regulation above station.



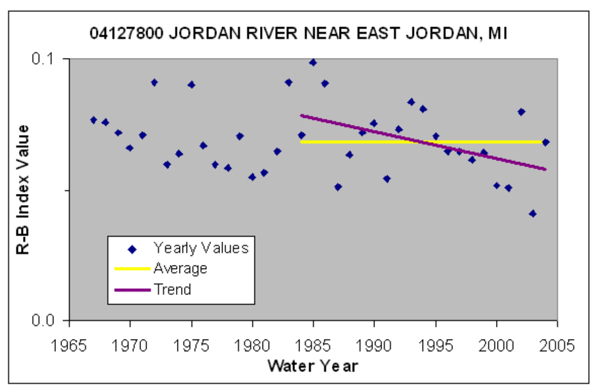
USGS Gage 04126740 – Some diversion for fish hatchery six miles upstream from station.



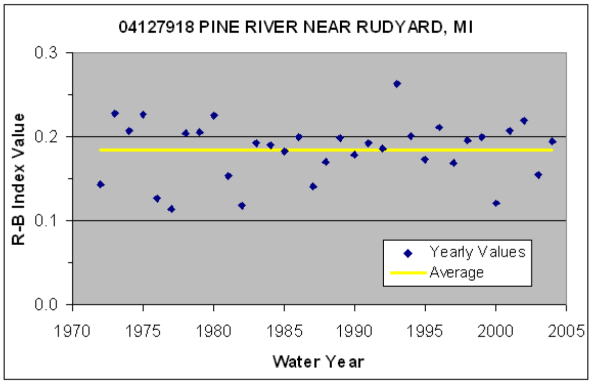
USGS Gage 04126970



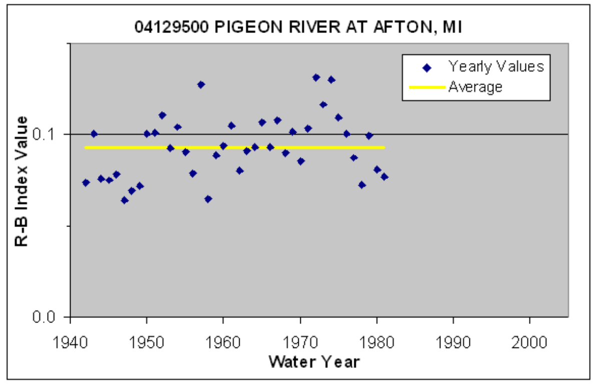
USGS Gage 04127000 – Flow regulated by hydroelectric power plant nine miles above station.



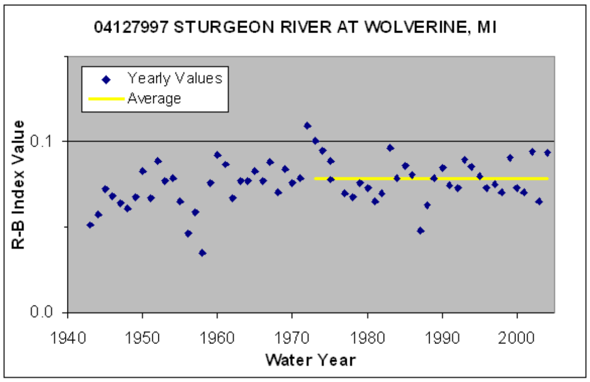
USGS Gage 04127800 – Some regulation at low flow by fish hatchery upstream from station.



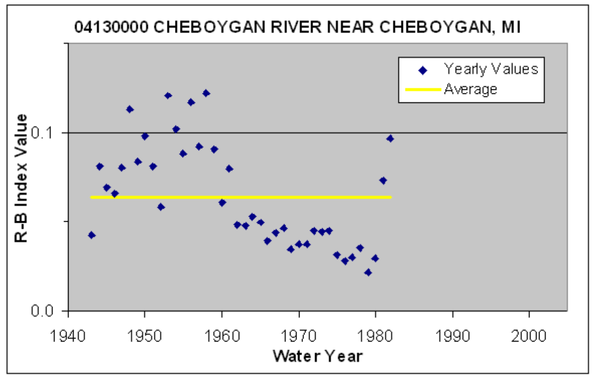
USGS Gage 04127918



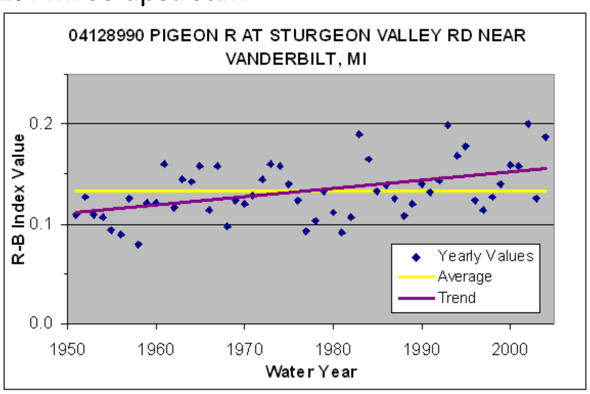
USGS Gage 04129500 – Prior to May 16, 1957 and since April 22, 1958 occasional regulation by Lansing Club Dam 22 miles above station.



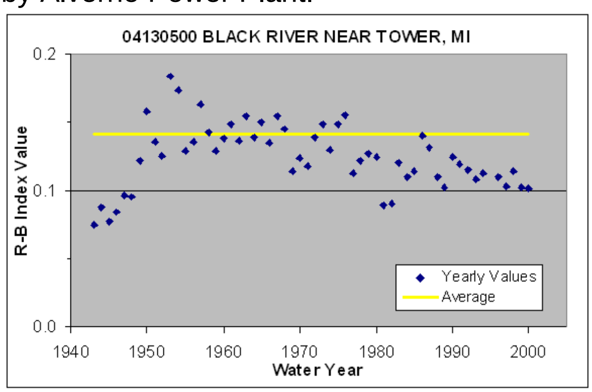
USGS Gage 04127997 – discontinued gage 04128000 considered equivalent. Prior to July 1975 intermittent regulation low flows from pond 2.4 miles upstream



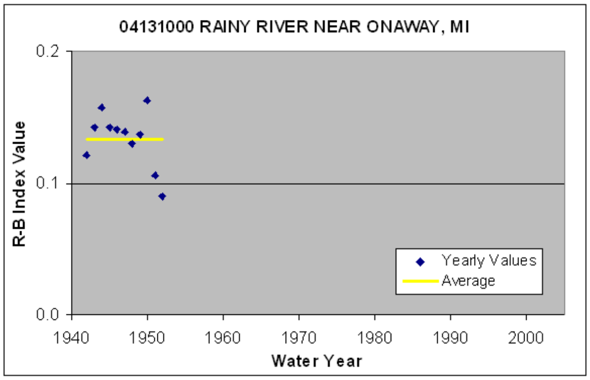
USGS Gage 04130000 – Flow regulated by dam in Cheboygan, prior to December 31, 1965 flow affected by variable backwater from power plant in Cheboygan 5.2 miles below station and by Alverno Power Plant.



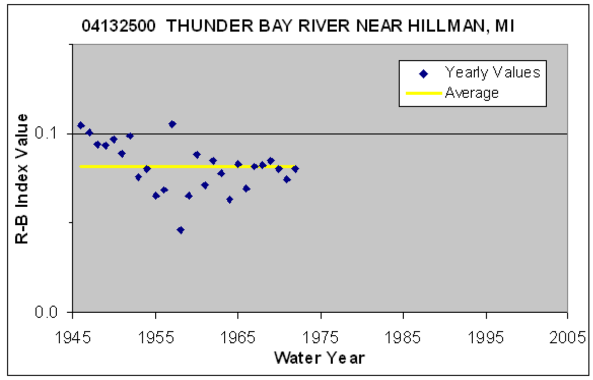
USGS Gage 04128990 – Prior to May 1967 and since April 22, 1958 regulation by Lansing Club Dam one mile upstream.



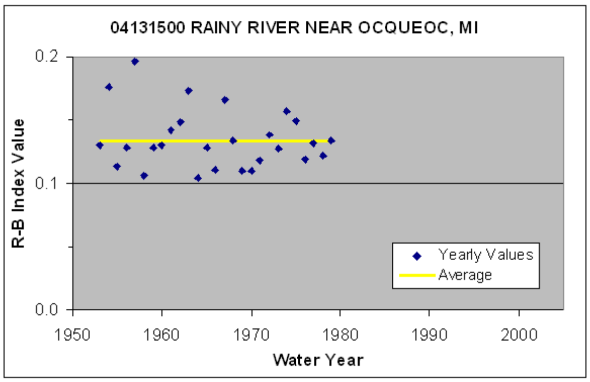
USGS Gage 04130500 – Completely regulated by Kebler Dam 400 feet upstream.



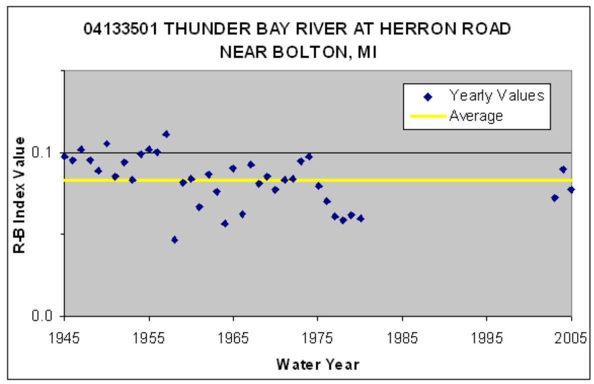
USGS Gage 04131000



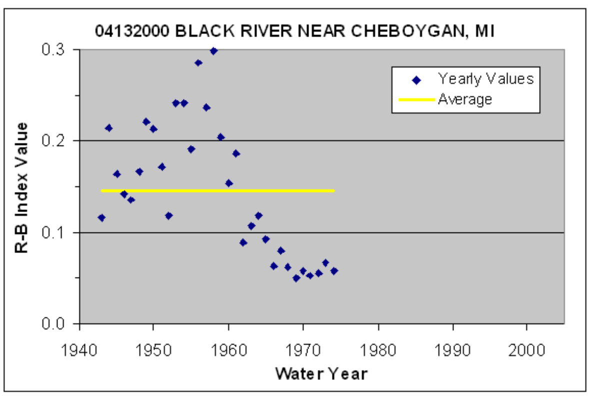
USGS Gage 04132500 – Prior to May 12, 1950 diurnal fluctuation below about 500 cubic feet per second by power plant at Atlanta, occasional regulation from dams above station.



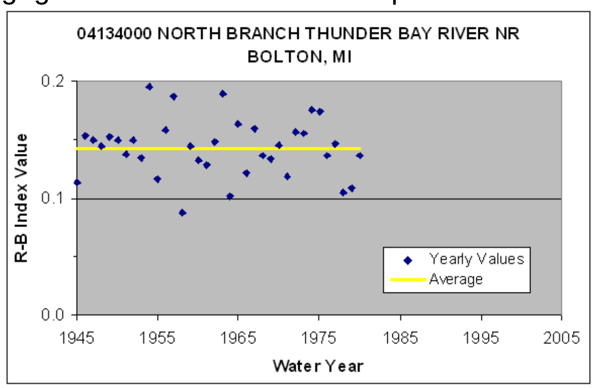
USGS Gage 04131500



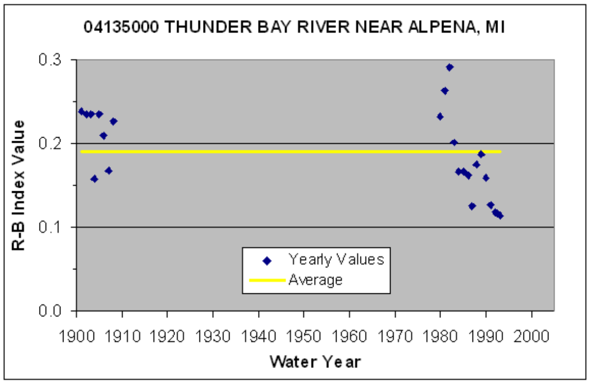
USGS Gage 04133501 – Occasional regulation by dams upstream from station, discontinued gage 04133500 considered equivalent.



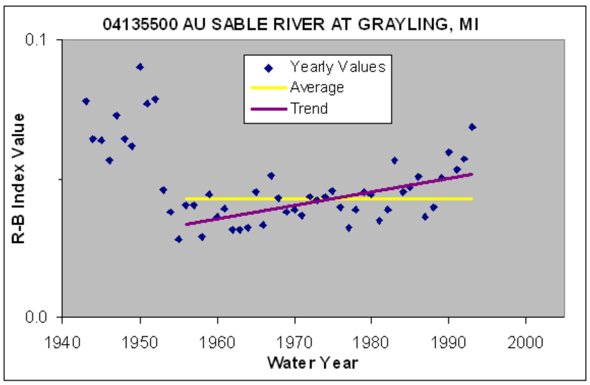
USGS Gage 04132000 – Flow regulated by Alverno Dam; prior to December 31, 1965 flow regulated by power plant at Alverno Dam.



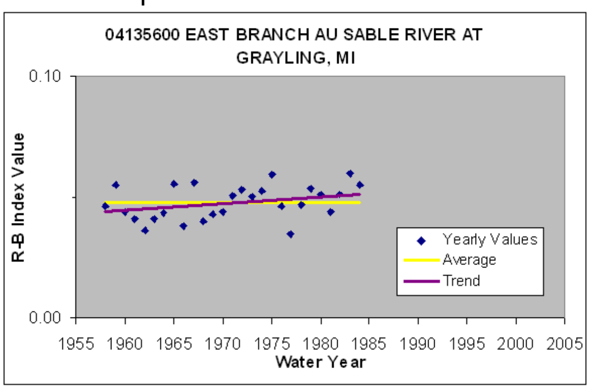
USGS Gage 04134000 – Occasional regulation during low flows by dam above station.



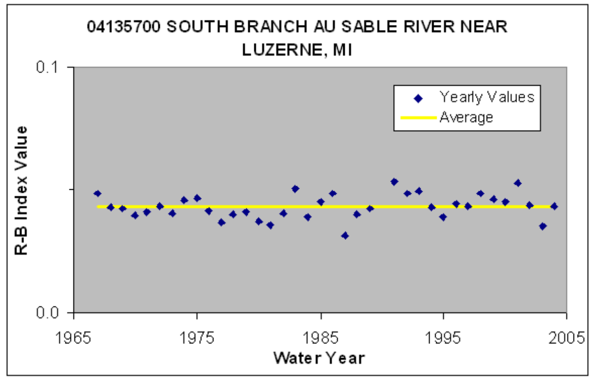
USGS Gage 04135000 – Flow regulated at all stages by hydroelectric power plant 1,000 feet upstream.



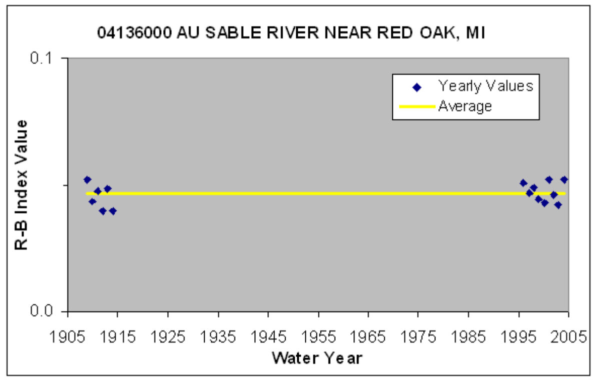
USGS Gage 04135500 – Prior to December 31, 1952 diurnal fluctuation caused by power plant 2.5 miles upstream.



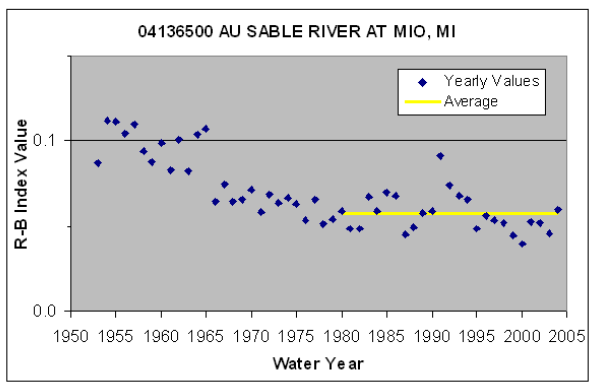
USGS Gage 04135600 – Occasional regulation by MDNR ponds above station.



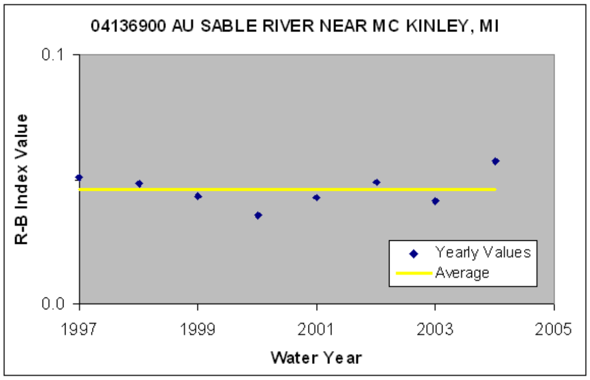
USGS Gage 04135700 – Occasional regulation by dam upstream from station.



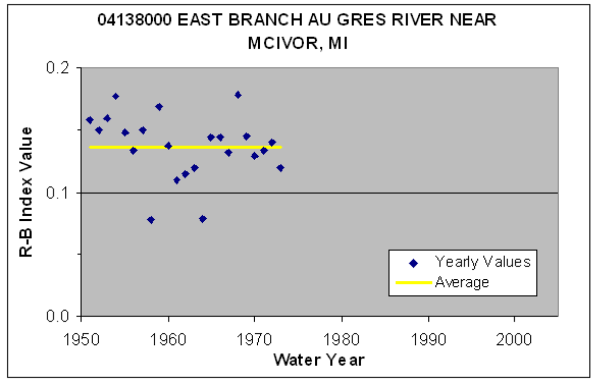
USGS Gage 04136000



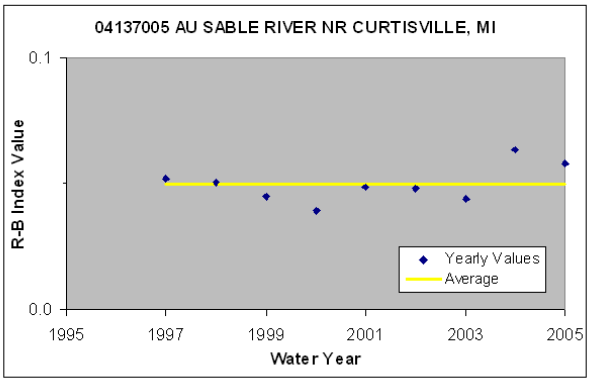
USGS Gage 04136500 – Flow regulated by Mio Dam 500 feet upstream.



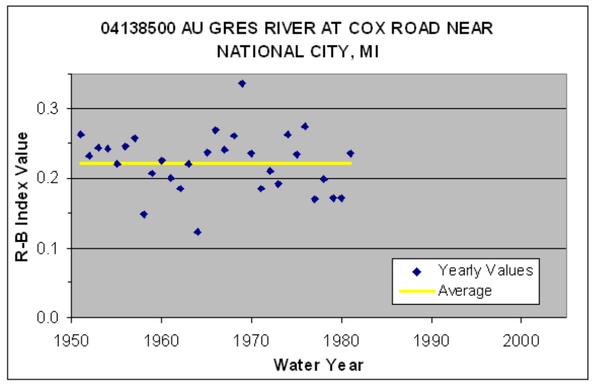
USGS Gage 04136900



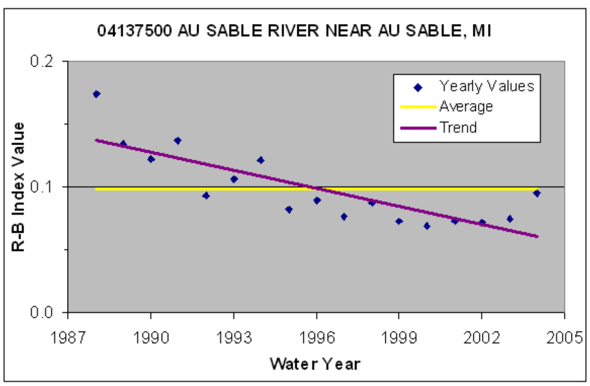
USGS Gage 04138000 – Some intermittent regulation at low and medium flow by dam 2.5 miles above station during period 1952-1966.



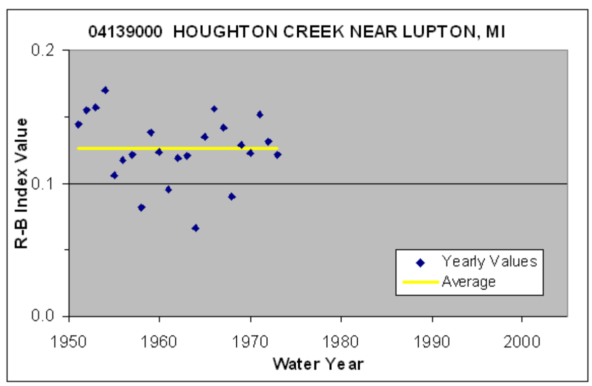
USGS Gage 04137005 – Flow completely regulated by Alcona Dam 300 feet upstream.



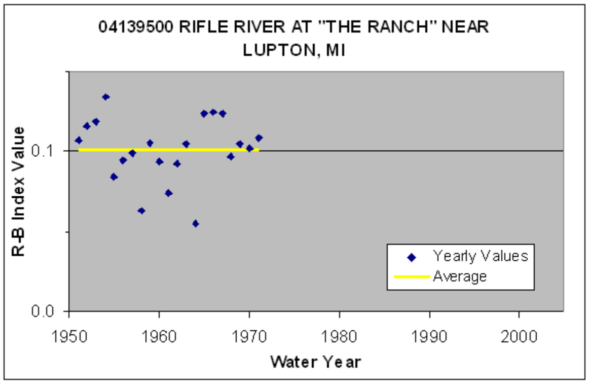
USGS Gage 04138500 – Some regulation at low flows.



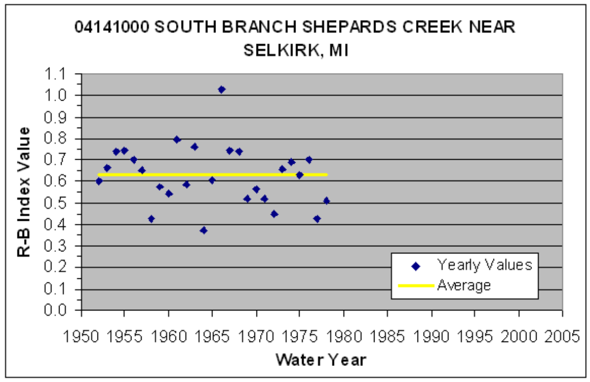
USGS Gage 04137500 – Flow regulated by Foote Dam 0.6 miles upstream.



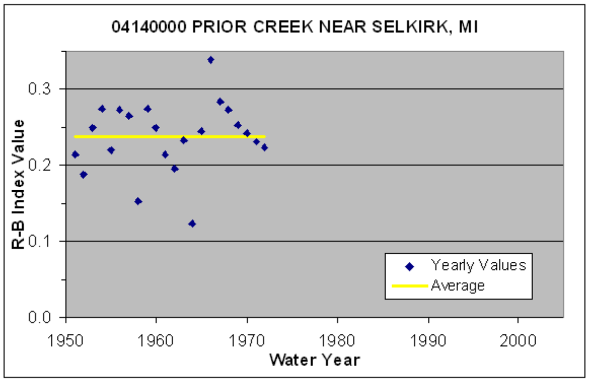
USGS Gage 04139000 – Intermittent regulation at low flow by sawmill on Sandback Creek at Rose City prior to June 1955 and since November 1958.



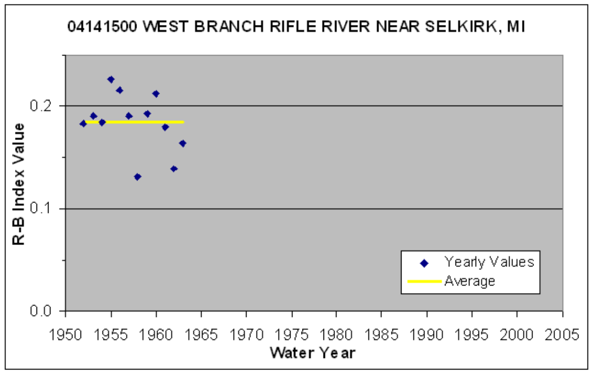
USGS Gage 04139500 – Occasional regulation by dams above station.



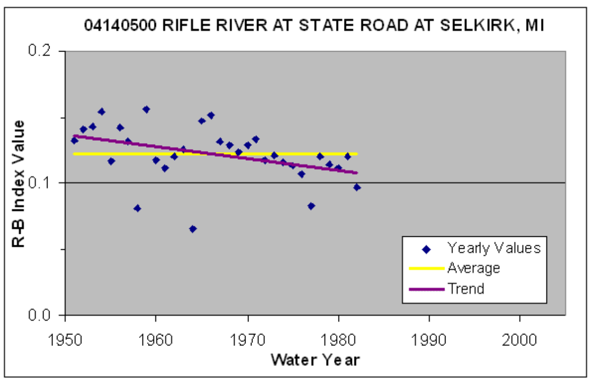
USGS Gage 04141000



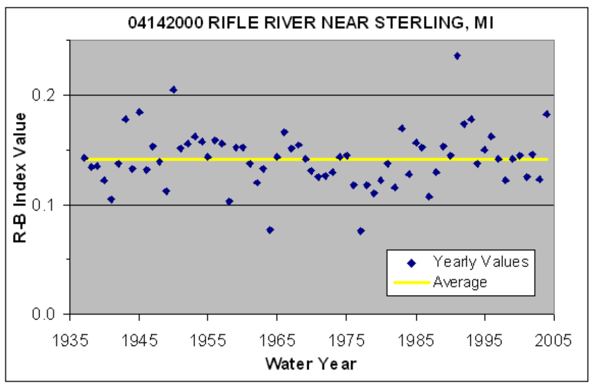
USGS Gage 04140000 – Some regulation from dam at lake outlet.



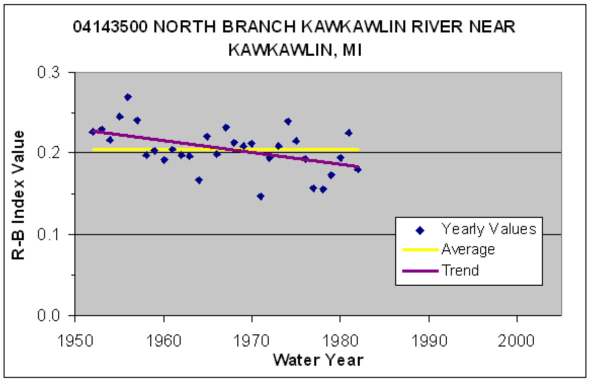
USGS Gage 04141500 – Occasional regulation from mill about seven miles upstream.



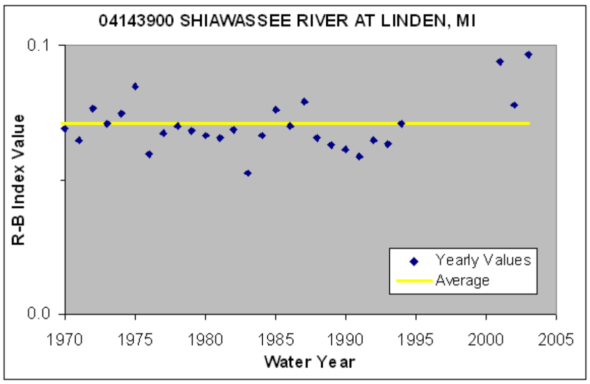
USGS Gage 04140500 – Some regulation by dams above station.



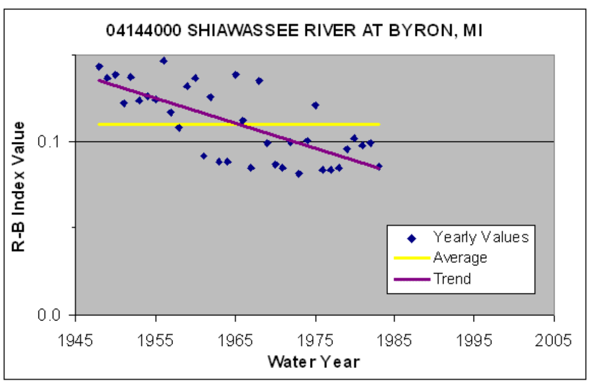
USGS Gage 04142000 – Occasional regulation by dams upstream from station.



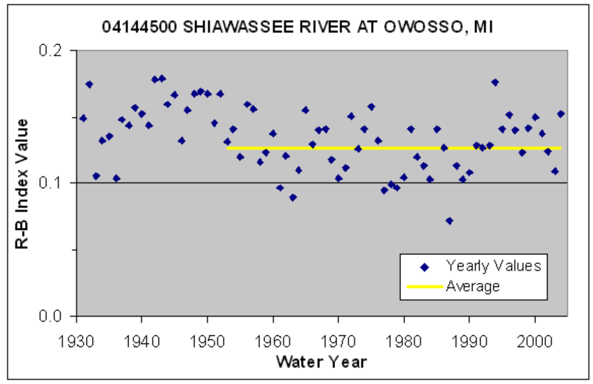
USGS Gage 04143500 – Some diversions above station for irrigation. Some regulation during low flows by dams above station.



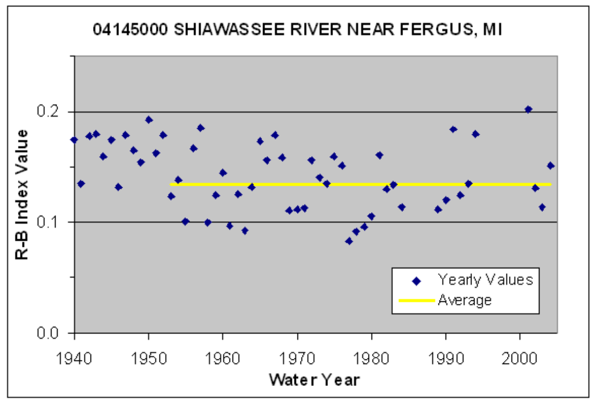
USGS Gage 04143900 – Flow regulated by dam at Liden since 1967.



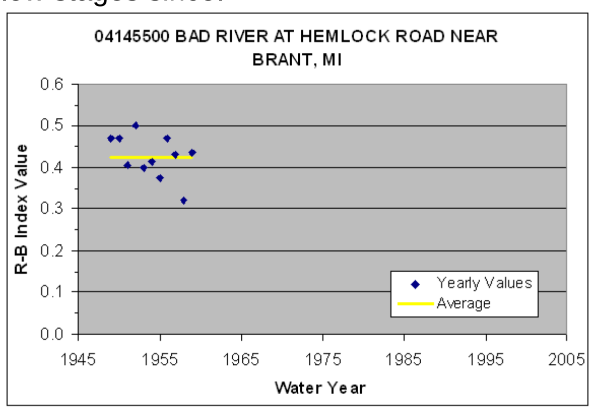
USGS Gage 04144000 – Low flow slightly regulated at times by mills above station.



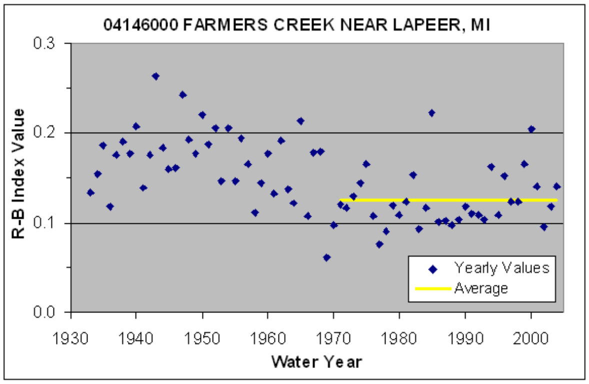
USGS Gage 04144500 – Flow regulated approximately 800 cubic feet per second by power plant at Shiawassee town prior to February 1953, occasional regulation at low stages since.



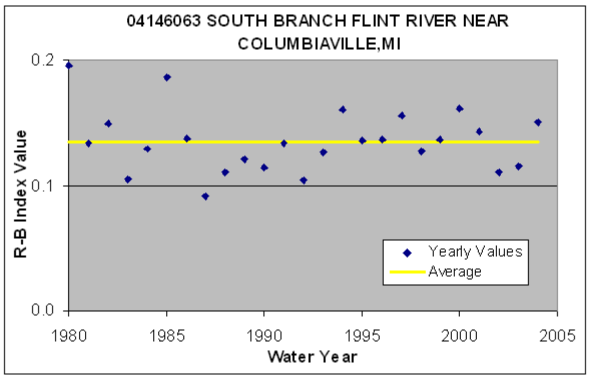
USGS Gage 04145000 – Some regulation at low stages by power plant at Shiawassee town prior to February 1953, occasional regulation at low stages since.



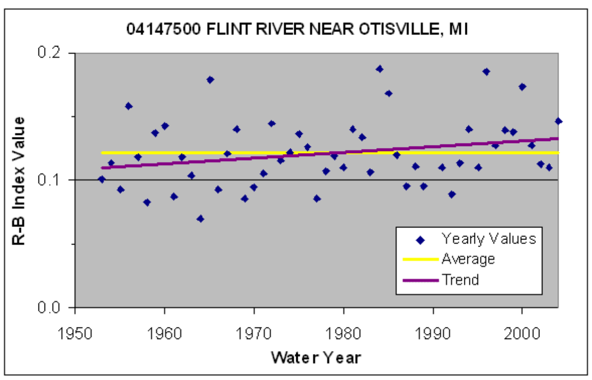
USGS Gage 04145500



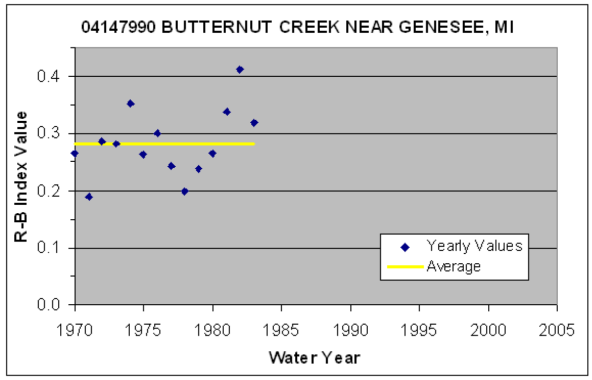
USGS Gage 04146000 – Prior to 1941 occasional regulation caused by Dam upstream from station.



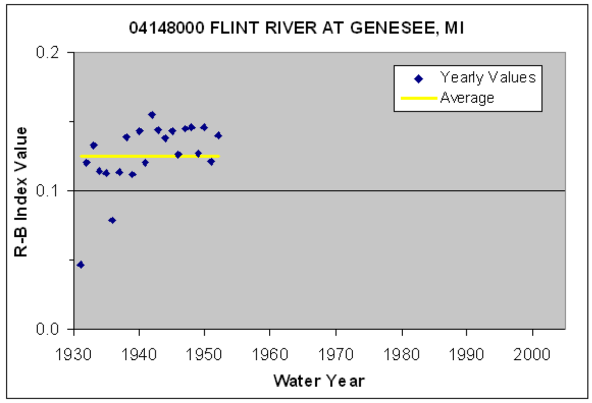
USGS Gage 04146063



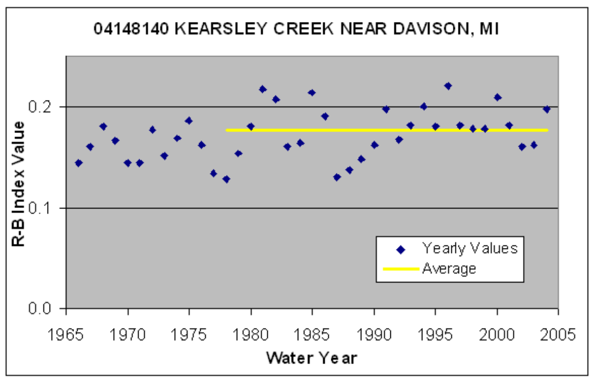
USGS Gage 04147500 – Flow regulated by Holloway reservoir 1.5 miles upstream from station. From 1954 to 1991 annual mean discharge and runoff adjusted for change in contents in Holloway Reservoir.



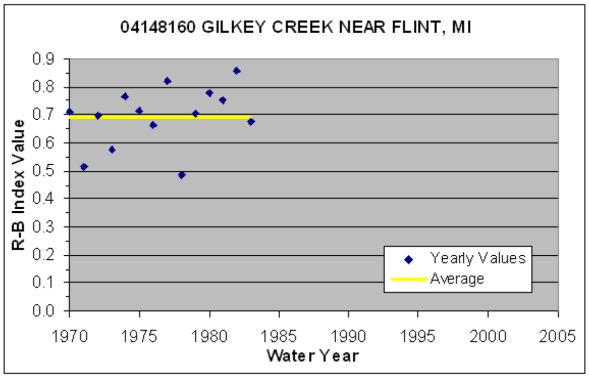
USGS Gage 04147990



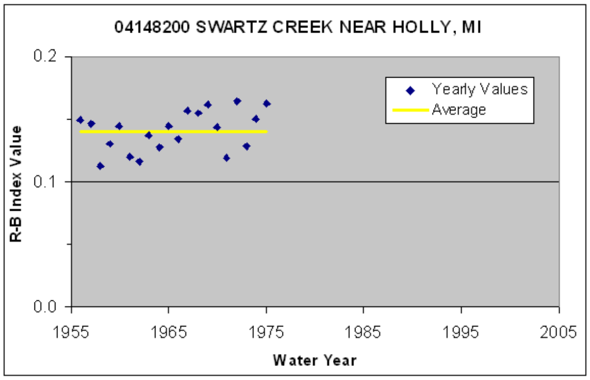
USGS Gage 04148000



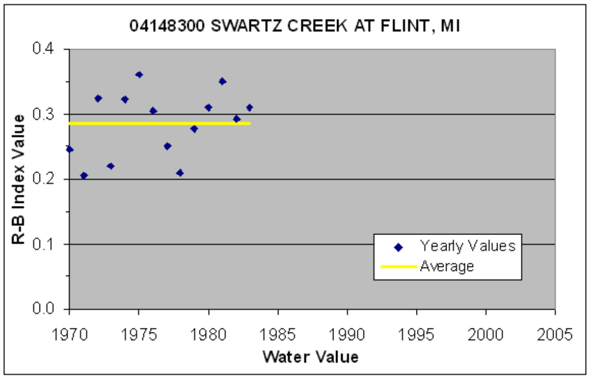
USGS Gage 04148140 – Some diurnal fluctuation caused by small dams and occasional diversion from irrigation upstream from station.



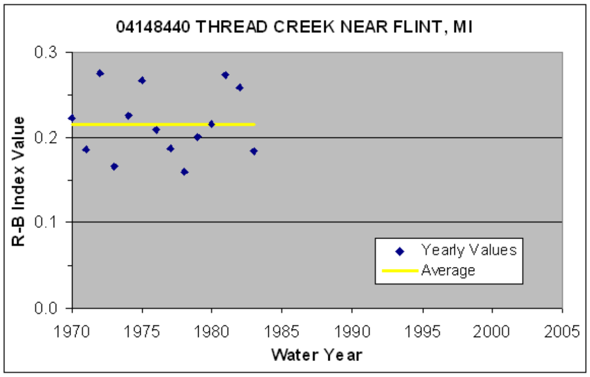
USGS Gage 04148160



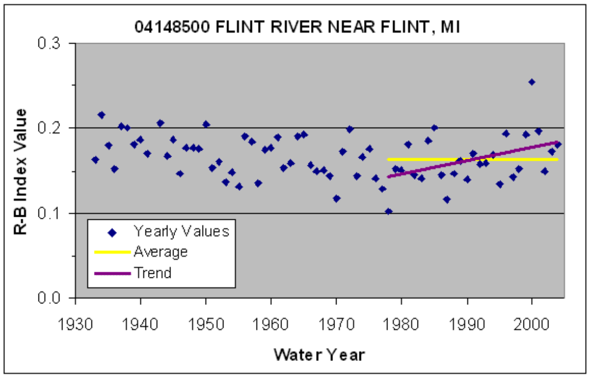
USGS Gage 04148200



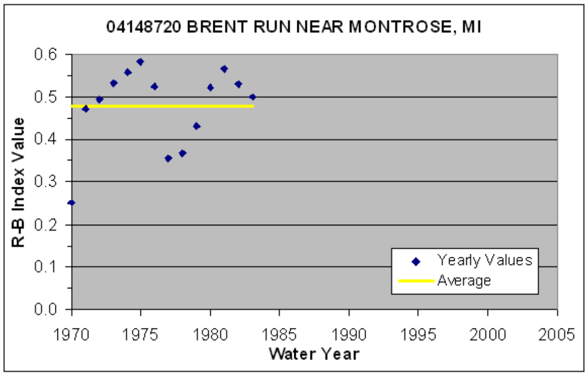
USGS Gage 04148300



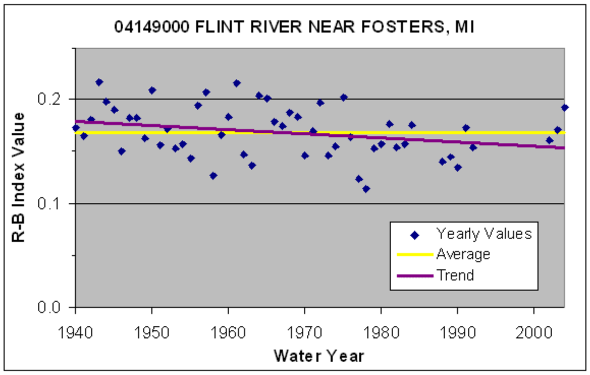
USGS Gage 04148440



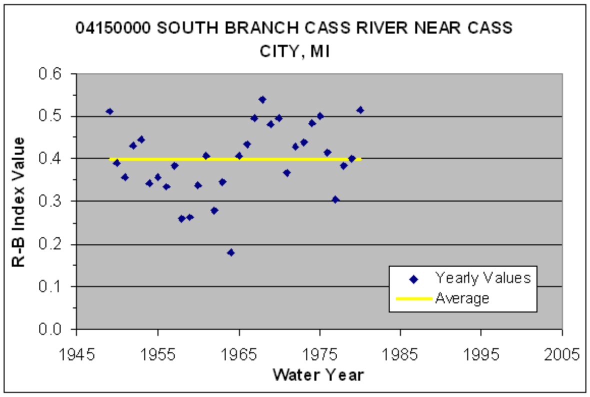
USGS Gage 04148500 – Some regulation by small reservoirs upstream from station and by Holloway reservoir. From 1954 to 1991 annual mean discharge and runoff figures adjusted for change in contents in Holloway Reservoir occasional diversion for industrial use. Since 1967 flow contains up to fifty cubic feet per second as sewage effluent which originates outside the basin.



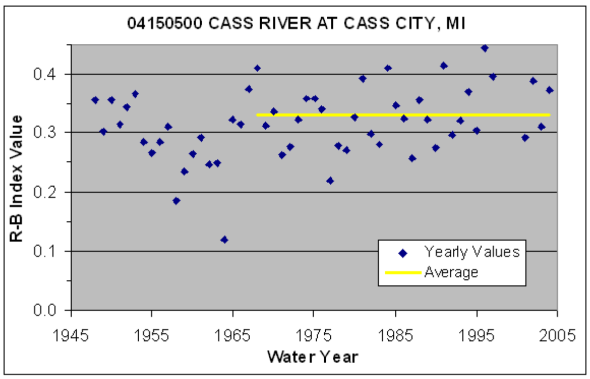
USGS Gage 04148720



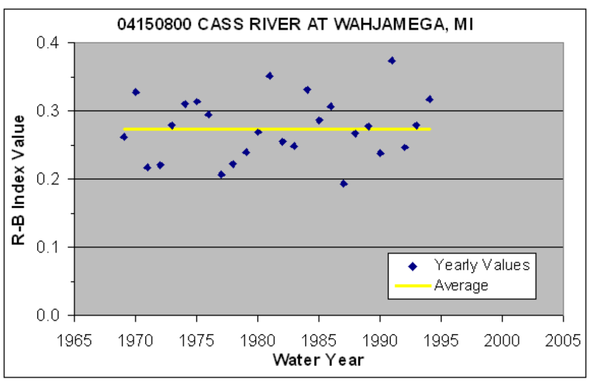
USGS Gage 04149000 – Prior to October 1, 1992 water stage records include flow of Birch Run, some regulation by reservoirs upstream from the City of Flint.



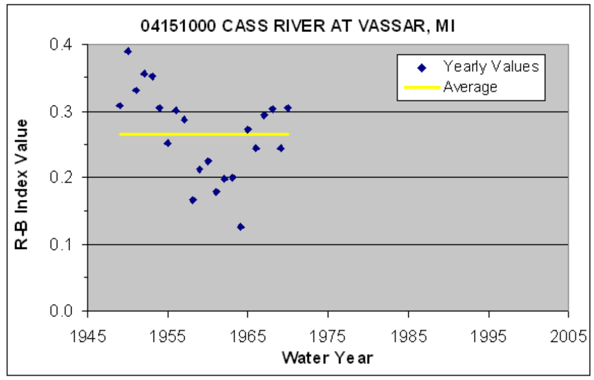
USGS Gage 04150000



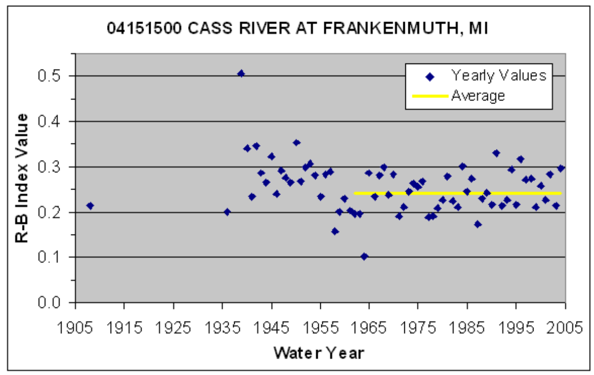
USGS Gage 04150500



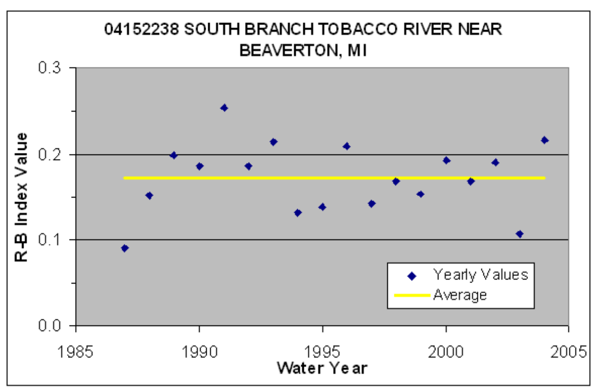
USGS Gage 04150800 – Some regulation by dam at Michigan Sugar Company 1.9 miles upstream from station.



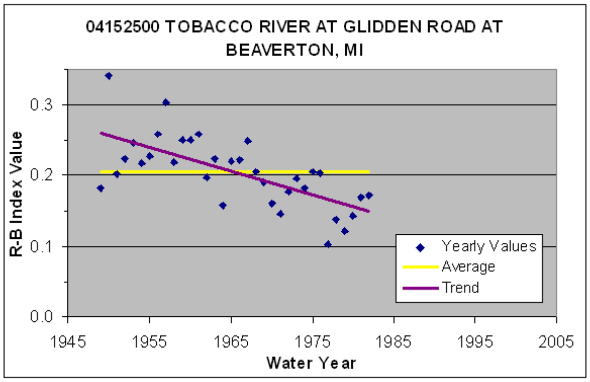
USGS Gage 04151000 – Some regulation by dam at Michigan Sugar Company 12.6 miles above station.



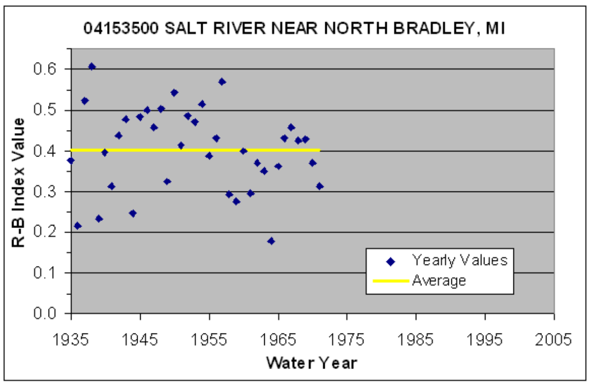
USGS Gage 04151500 – Occasional regulation by dams upstream from station. Prior to 1950 regulation at low and medium flows by mill upstream from station.



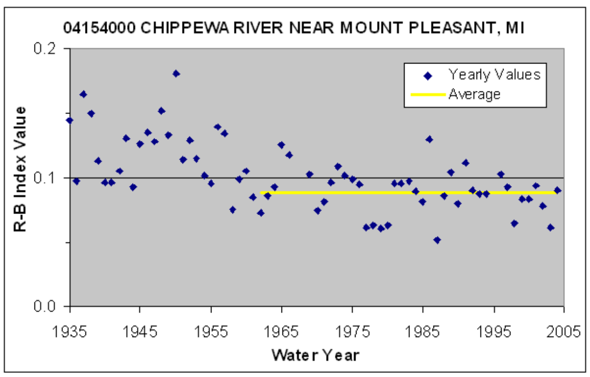
USGS Gage 04152238



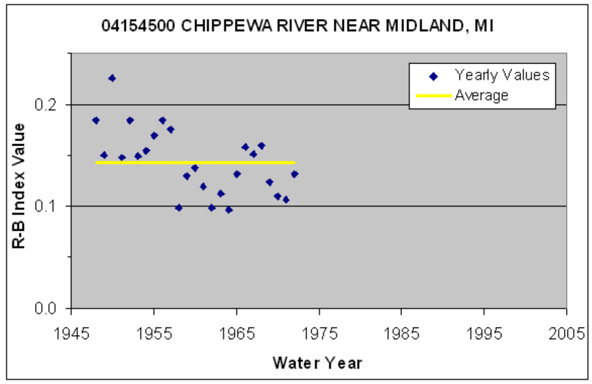
USGS Gage 04152500 – Prior to February 21, 1961 regulation at all stages by hydroelectric power plant one mile above station, occasional regulation since.



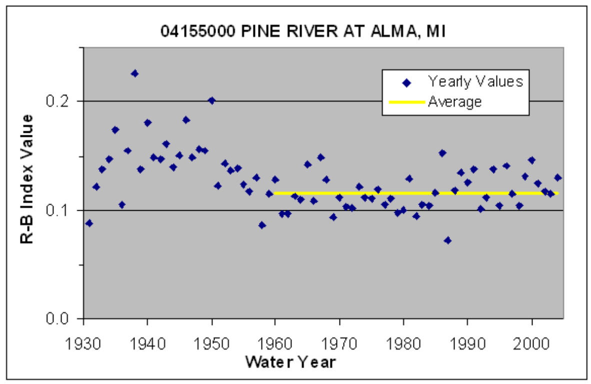
USGS Gage 04153500



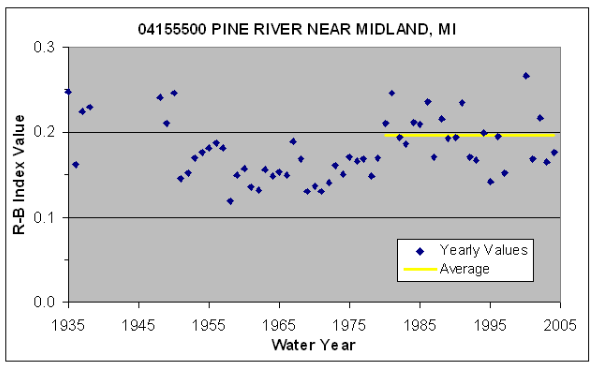
USGS Gage 04154000 – Diurnal fluctuation below 750 cubic feet per second caused by power plant at Mount Pleasant prior to 1962, occasional regulation at low flow since. Since July 30, 1968 occasional regulation from control structures on lake outlets.



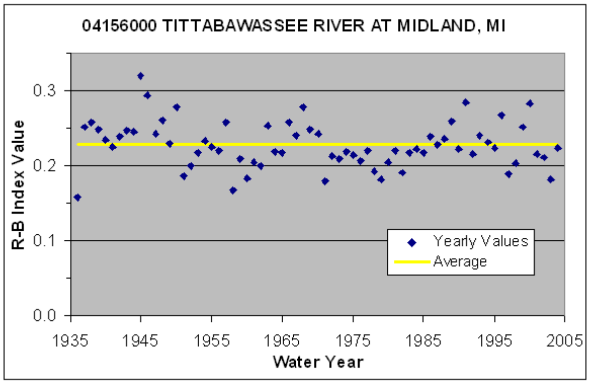
USGS Gage 04154500 – Diurnal fluctuation below 750 cubic feet per second caused by power plant at Mount Pleasant prior to 1962, occasional regulation at low flow since. Since July 30, 1968 occasional regulation from control structures on lake outlets.



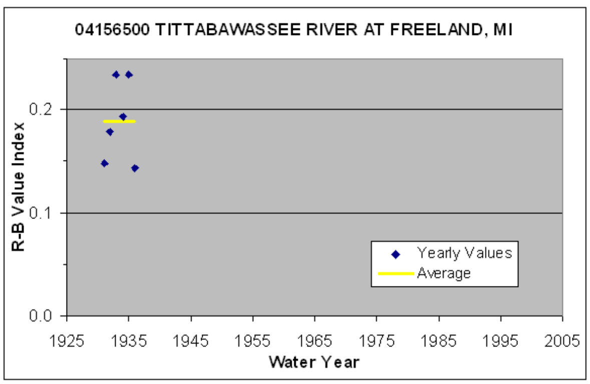
USGS Gage 04155000 – Flow regulated by dam 0.6 miles upstream from station, and by variable backwater from power plant at St. Louis 5.2 miles downstream.



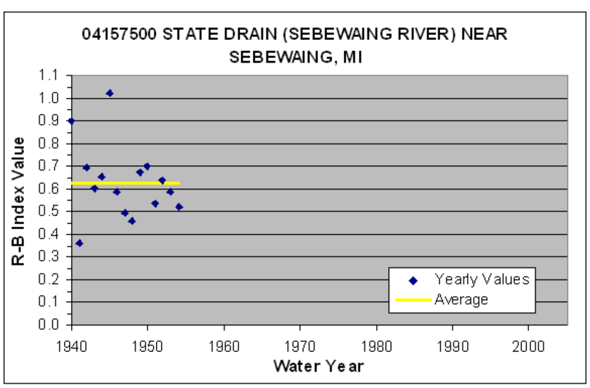
USGS Gage 04155500 – Regulation at low and medium flows by hydroelectric power plant at St. Louis. Some diversions from station for irrigation.



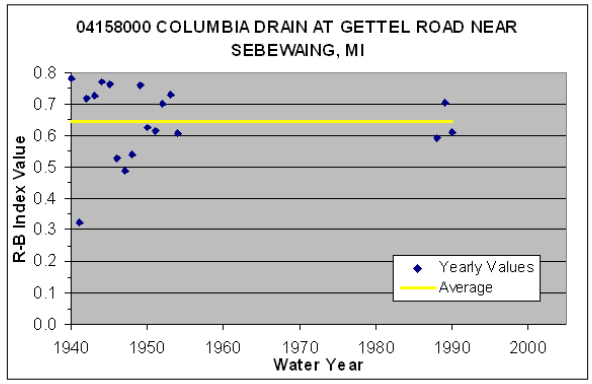
USGS Gage 04156000 – Prior to 1992 a diversion was used in computing annual mean discharge and runoff figures, extremes and daily discharge were not adjusted for diversion. Prior to May 20, 1970 discharge below 4,000 cubic feet per second regulated by dam 2,000 feet upstream from station; fixed crest dam.



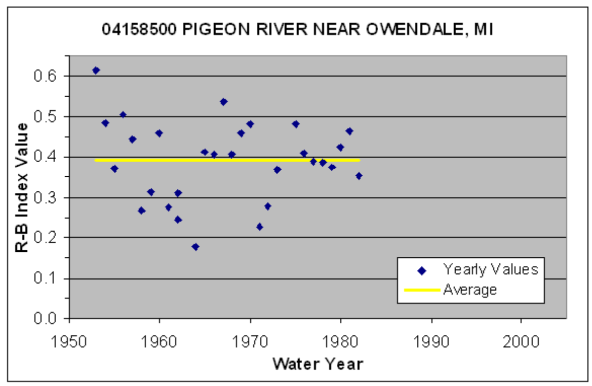
USGS Gage 04156500



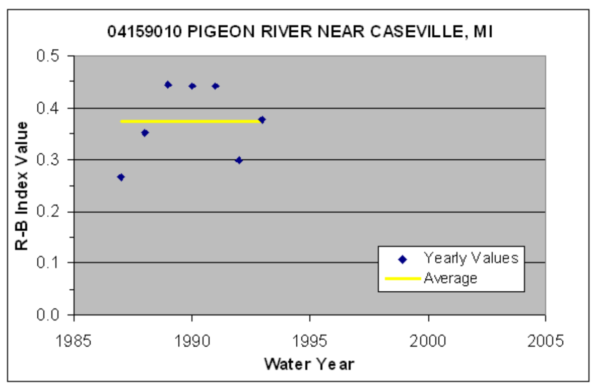
USGS Gage 04157500



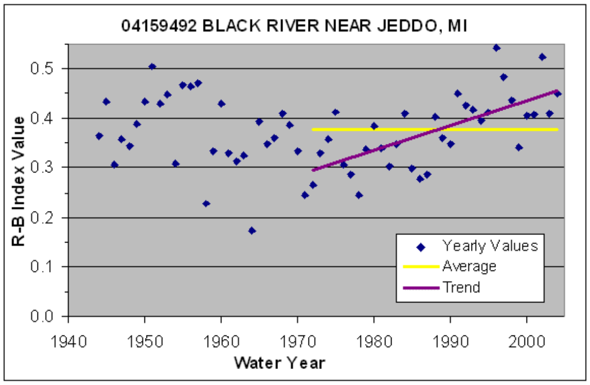
USGS Gage 04158000 – Some regulation by dam at Michigan Sugar Company 1.9 miles upstream from station.



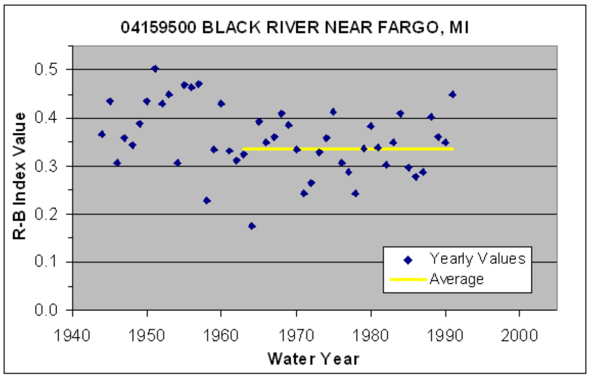
USGS Gage 04158500



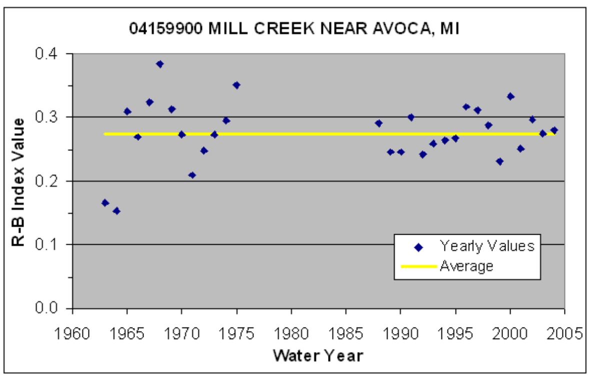
USGS Gage 04159010 – Some diversions at low flows for agricultural irrigation.



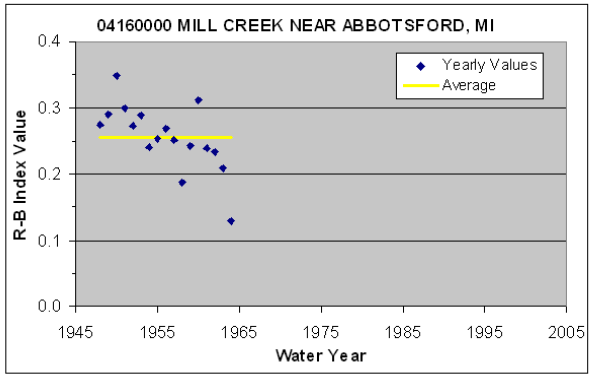
USGS Gage 04159492 – Diurnal fluctuation principally during low flow, caused by an unknown source upstream from station.



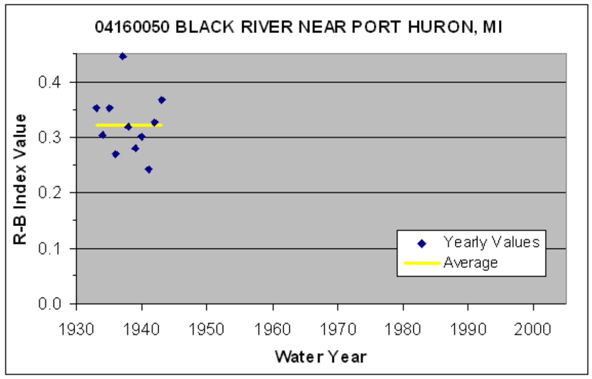
USGS Gage 04159500



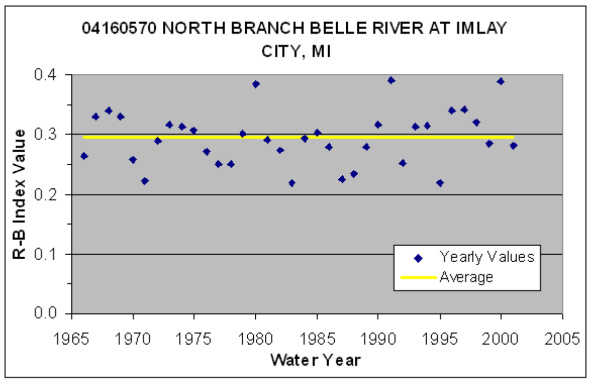
USGS Gage 04159900



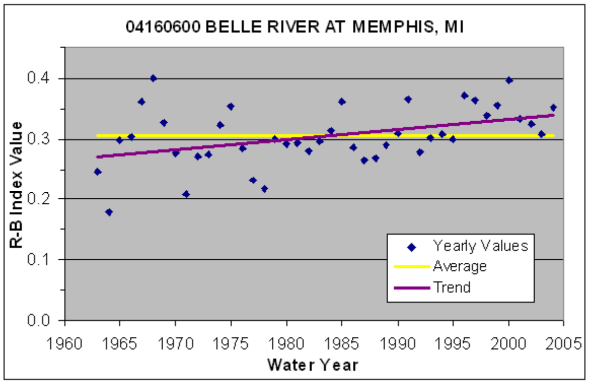
USGS Gage 04160000



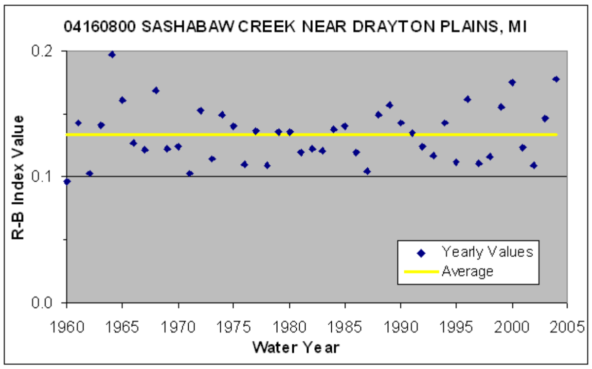
USGS Gage 04160050



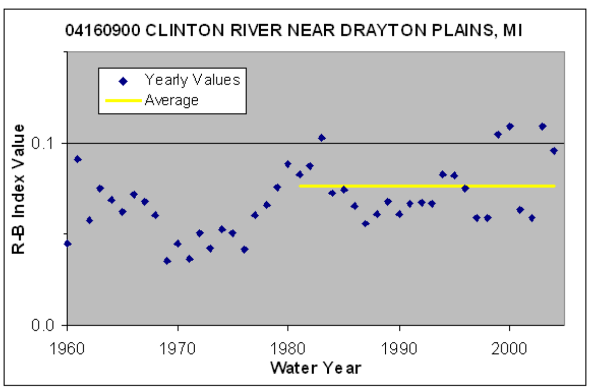
USGS Gage 04160570 – Some diversion by pumping for sprinkler irrigation.



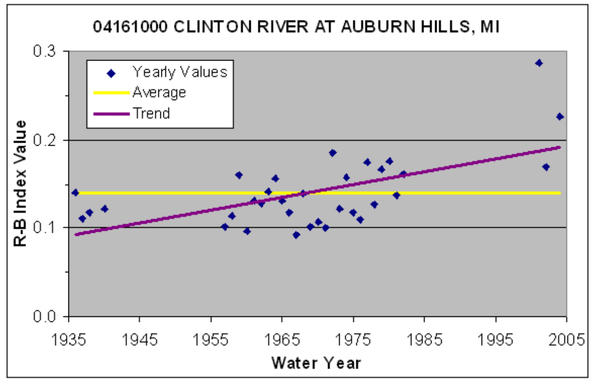
USGS Gage 04160600



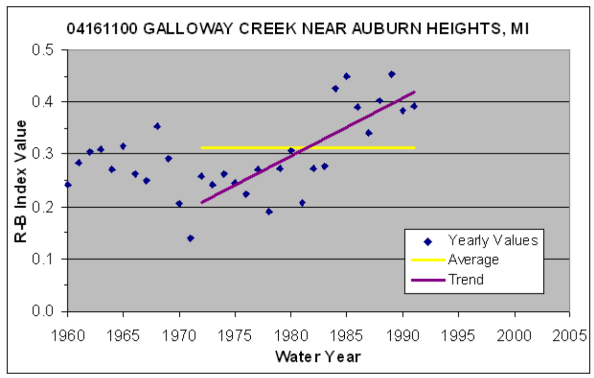
USGS Gage 04160800



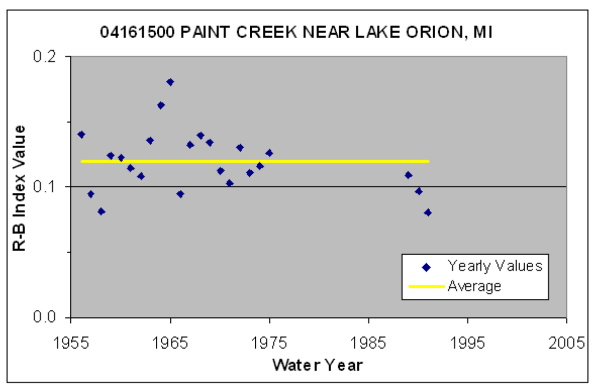
USGS Gage 04160900 – Some regulation and occasional diversion for lake-level control at many lakes upstream from station.



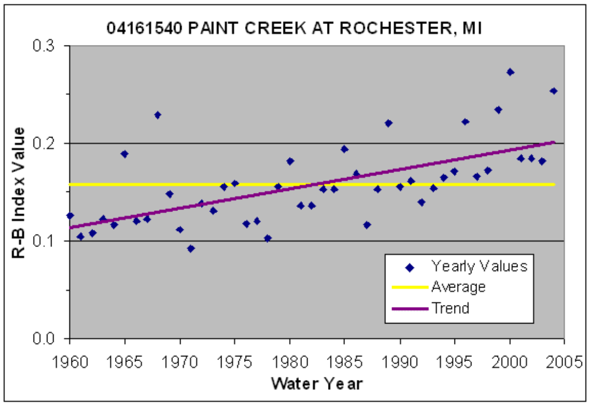
USGS Gage 04161000 – Some regulation by many lakes upstream from station. Flow includes sewage effluent, most of which originates from sources outside the Basin.



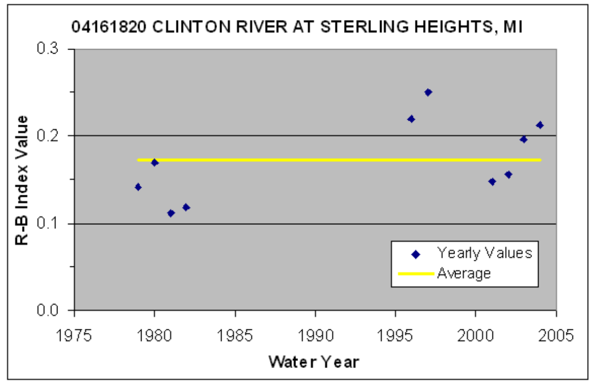
USGS Gage 04161100



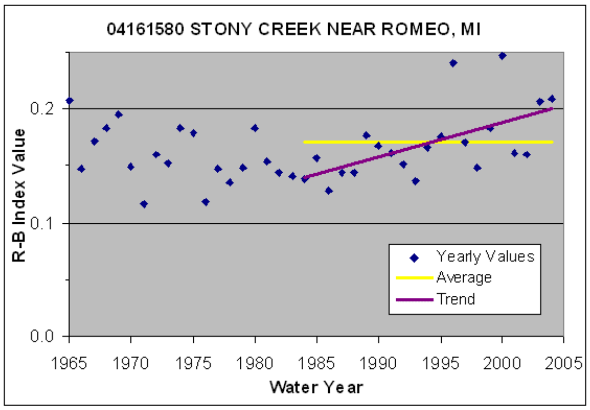
USGS Gage 04161500 – Occasional regulation by Lake Orion.



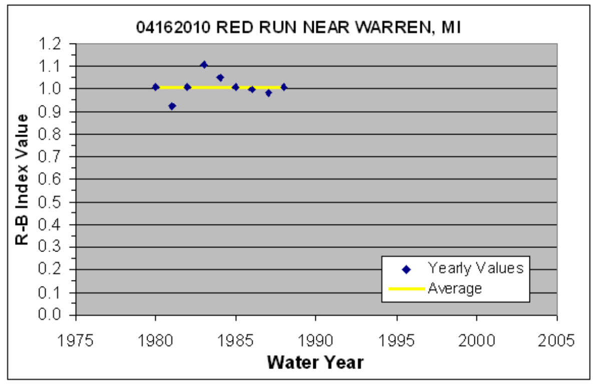
USGS Gage 04161540 – Occasional regulation by Lake Orion.



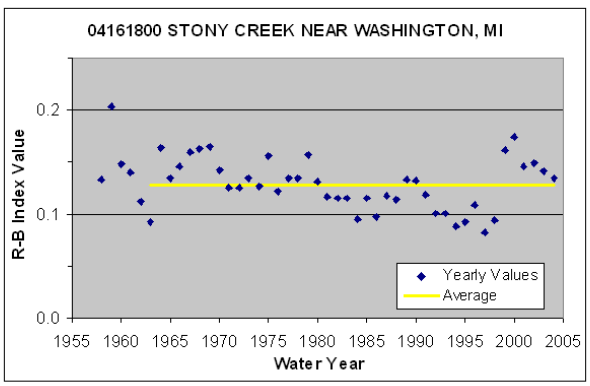
USGS Gage 04161820



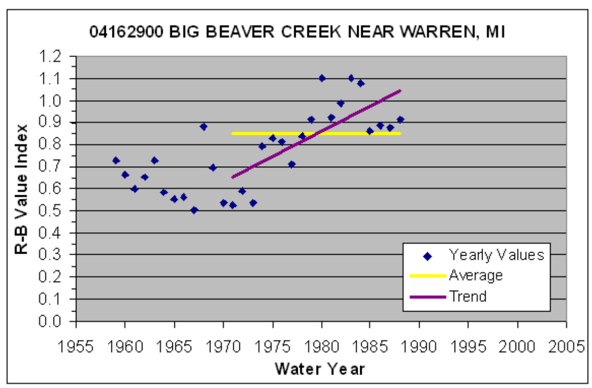
USGS Gage 04161580



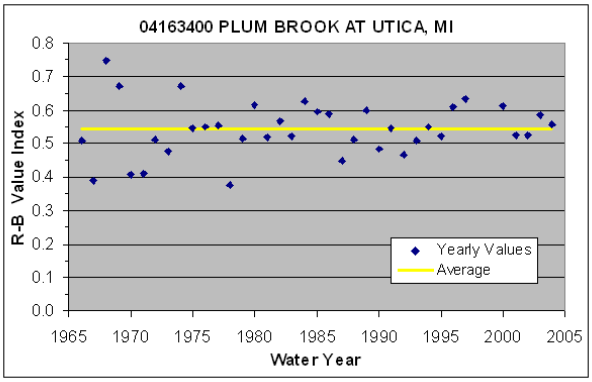
USGS Gage 04162010 – Diversions from Big Beaver Creek Basin via Henry-Graham Drain started in 1976 is ongoing and increasing with further development of new drains.



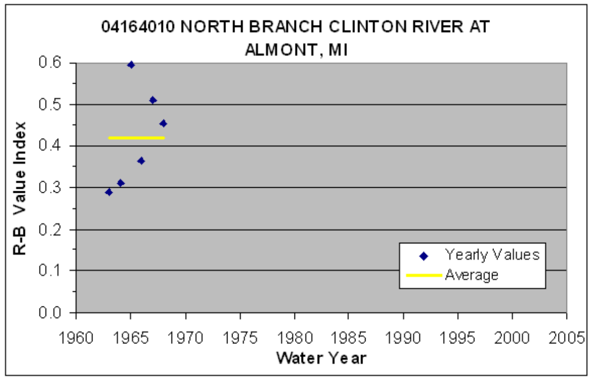
USGS Gage 04161800 – Occasional diurnal fluctuation caused by mills upstream from station prior to February 1963, occasional regulation by Stony Lake since.



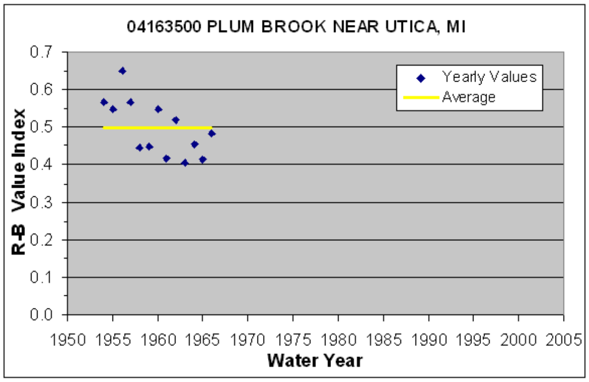
USGS Gage 04162900 – Diversions from the Henry-Graham Drain started in 1976 is ongoing and increasing with further development for new drains.



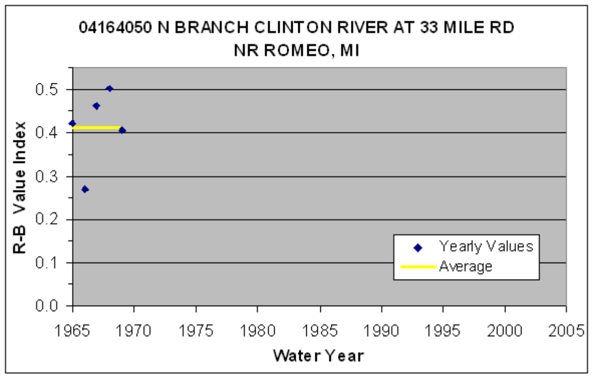
USGS Gage 04163400 – Prior to 1998 occasional diversion for sprinkler irrigation.



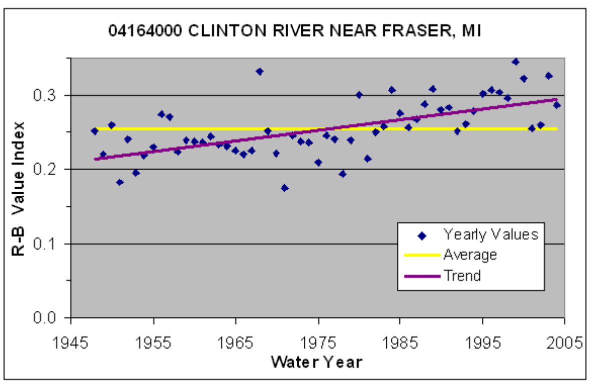
USGS Gage 04164010



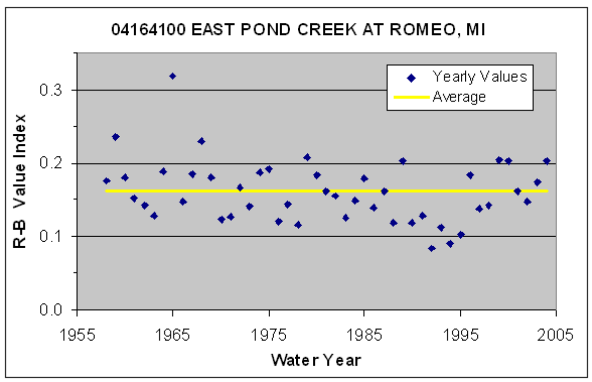
USGS Gage 04163500



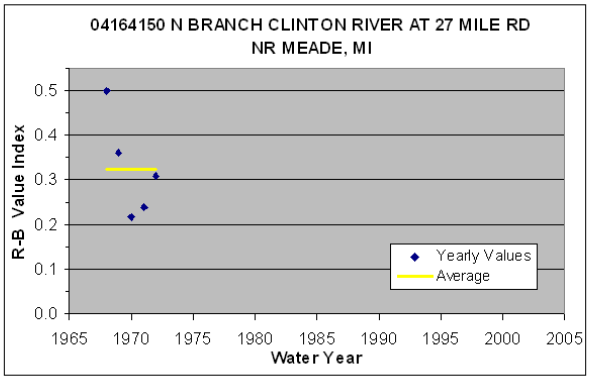
USGS Gage 04164050



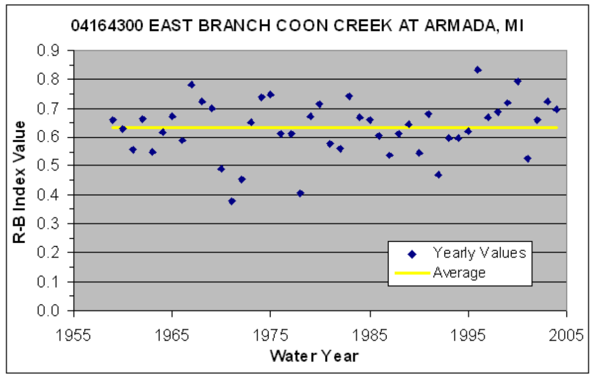
USGS Gage 04164000



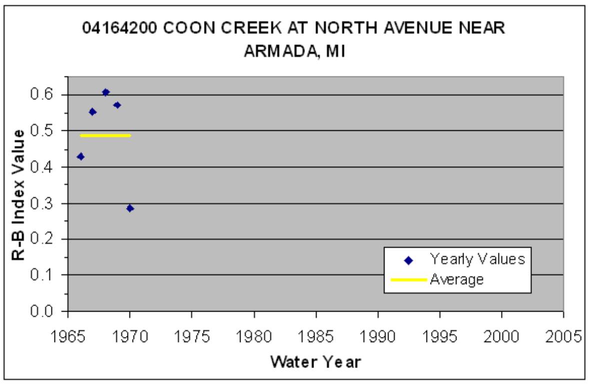
USGS Gage 04164100 – Occasional regulation upstream from station.



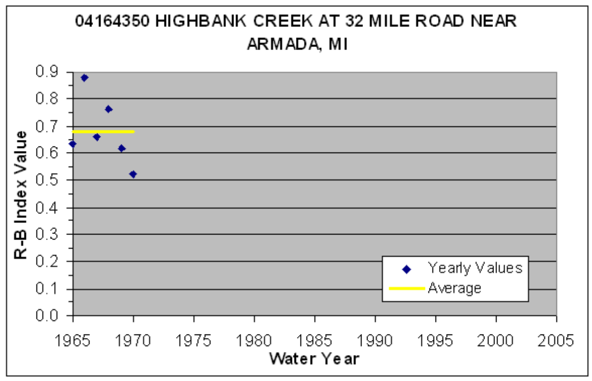
USGS Gage 04164150 – Occasional regulation at low flow by Mill Pond above station.



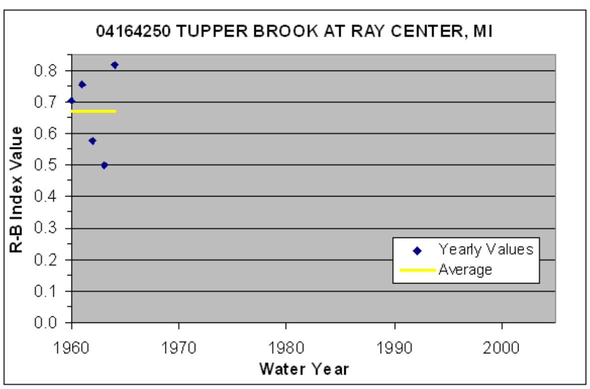
USGS Gage 04164300



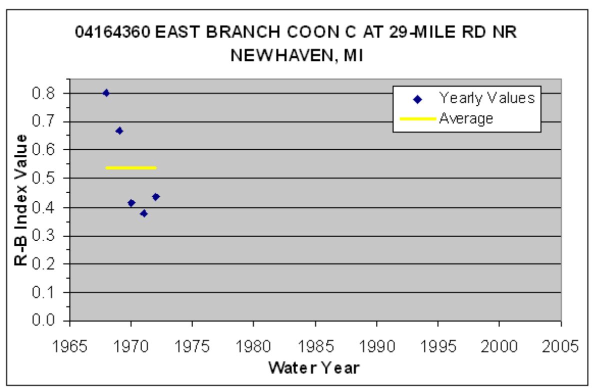
USGS Gage 04164200 – Occasional diversion for sprinkler irrigation.



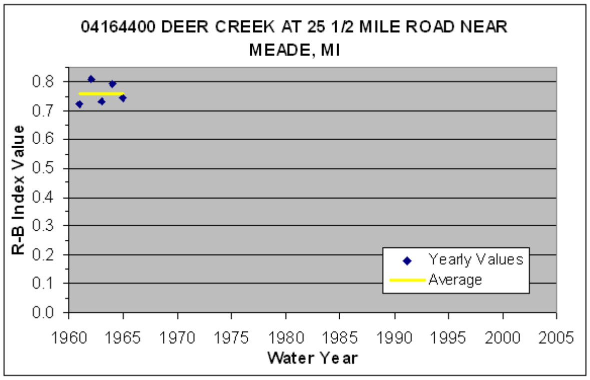
USGS Gage 04164350 – Occasional diversion for sprinkler irrigation.



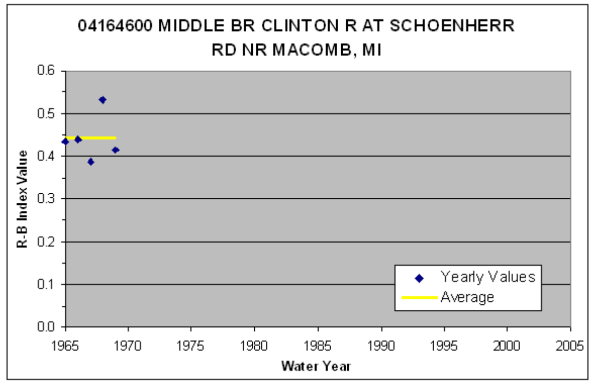
USGS Gage 04164250



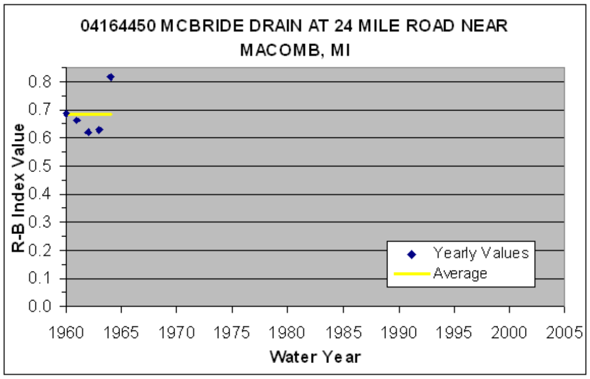
USGS Gage 04164360



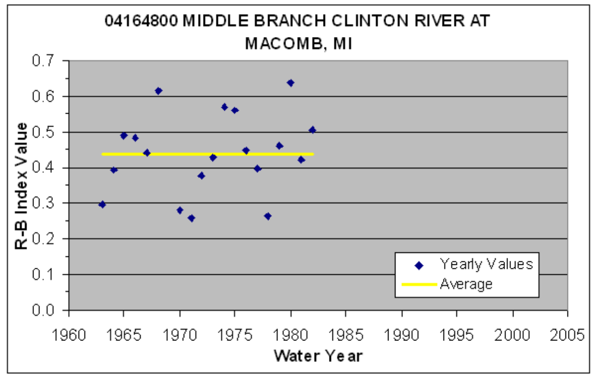
USGS Gage 04164400



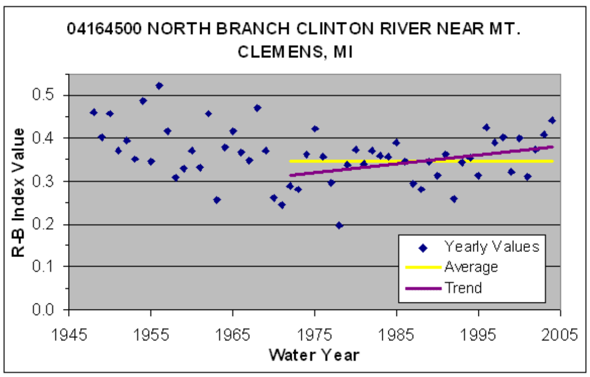
USGS Gage 04164600



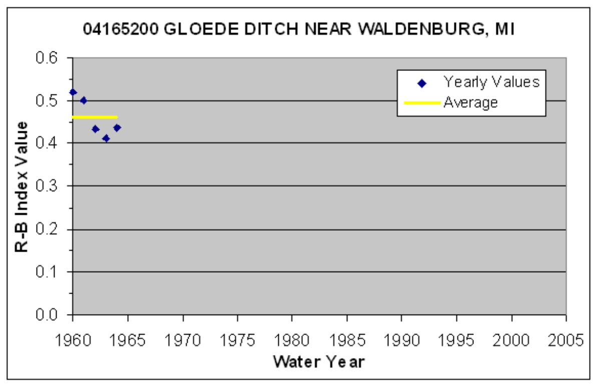
USGS Gage 04164450



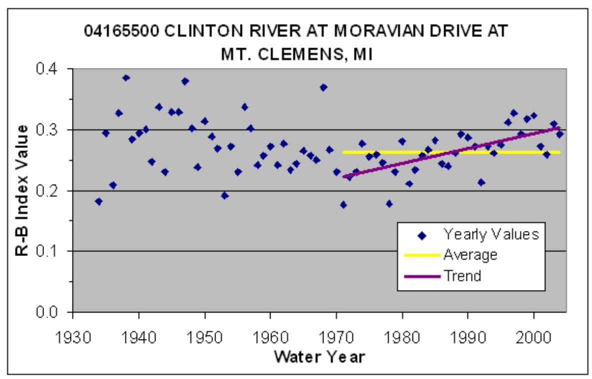
USGS Gage 04164800



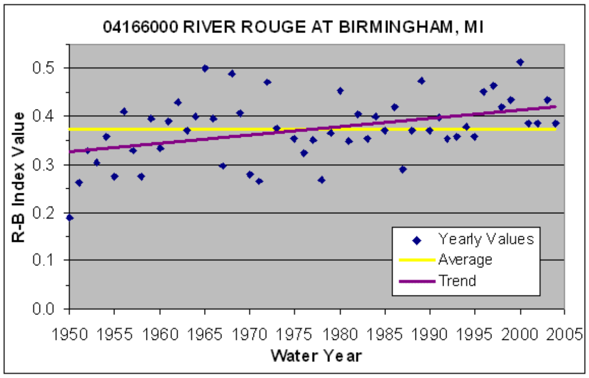
USGS Gage 04164500 – Some regulation by mill upstream.



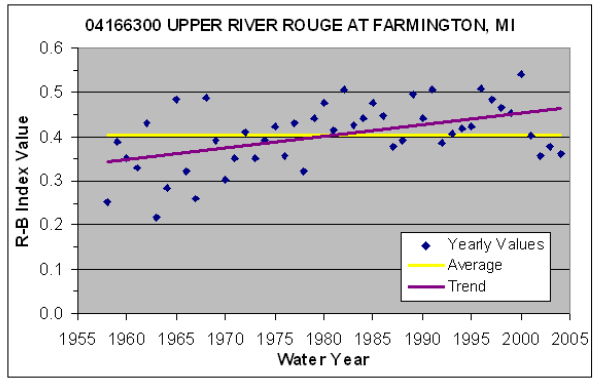
USGS Gage 04165200



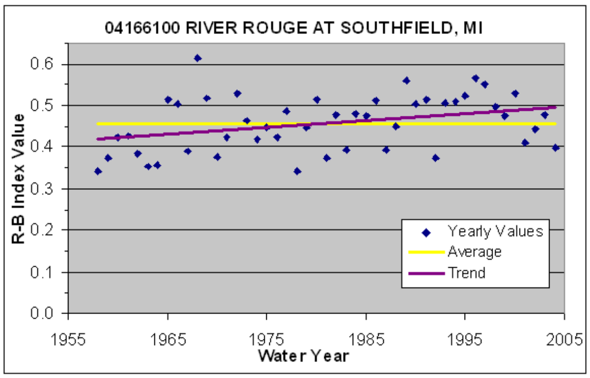
USGS Gage 04165500



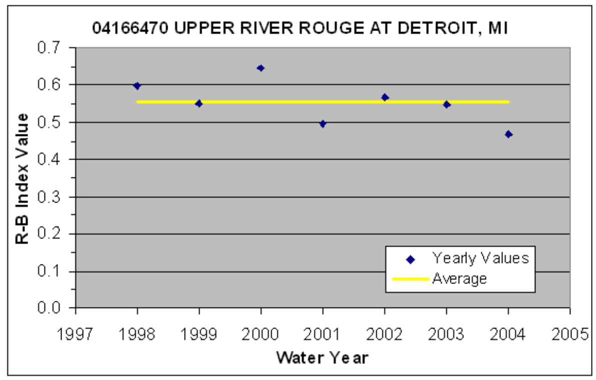
USGS Gage 04166000 – Occasional regulation by Quarton Lake upstream from station.



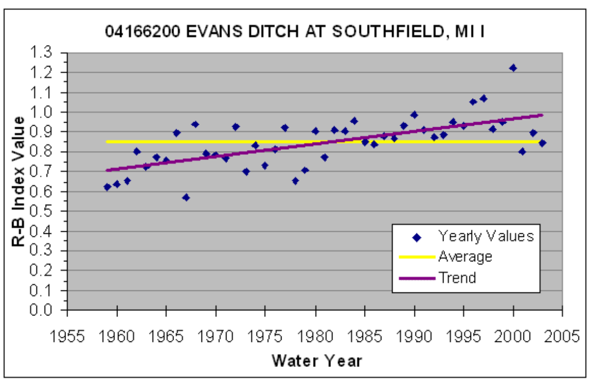
USGS Gage 04166300



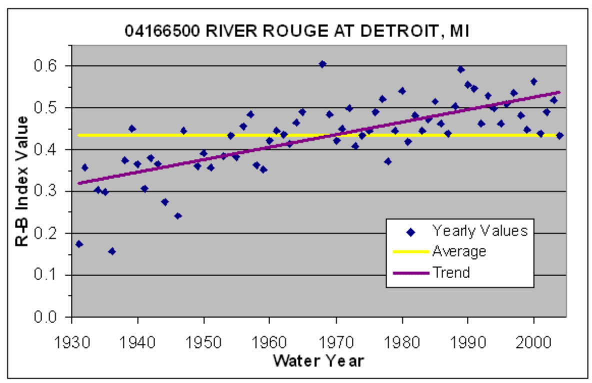
USGS Gage 04166100



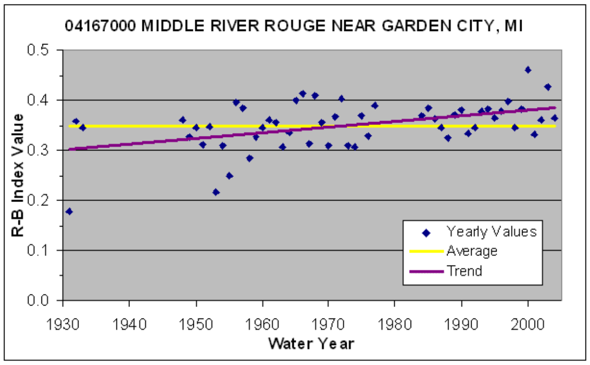
USGS Gage 04166470



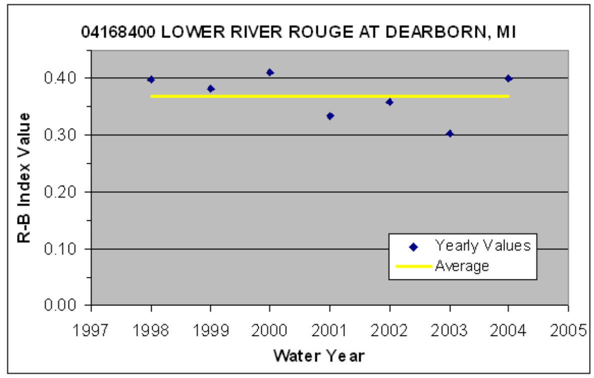
USGS Gage 04166200



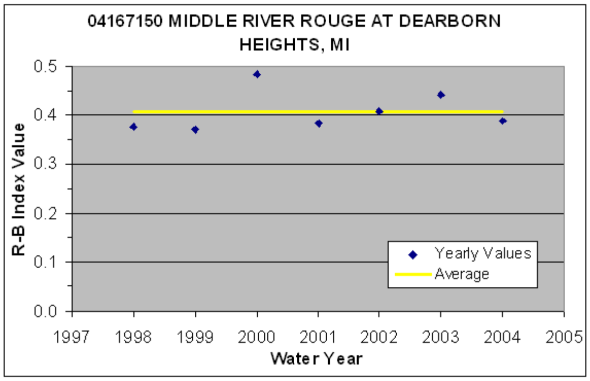
USGS Gage 04166500 – Regulation by water retention structure upstream from station and some diversion by pumping for sprinkler irrigation.



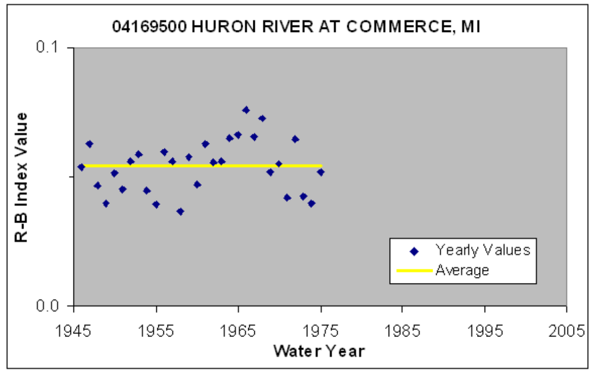
USGS Gage 04167000 – Regulation by storm water retention structures and occasional regulation by reservoirs upstream of the station since 1956.



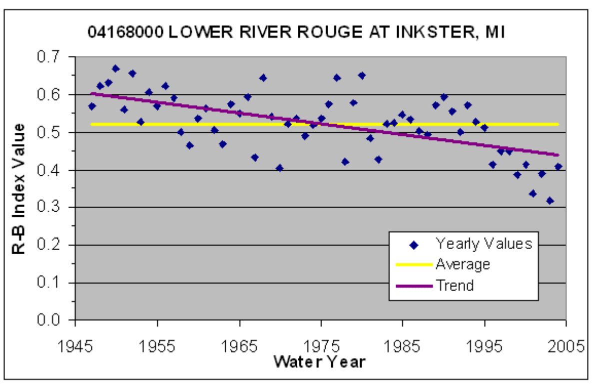
USGS Gage 04168400 – Flow contains effluent from sewage treatment plant, which originates outside the basin.



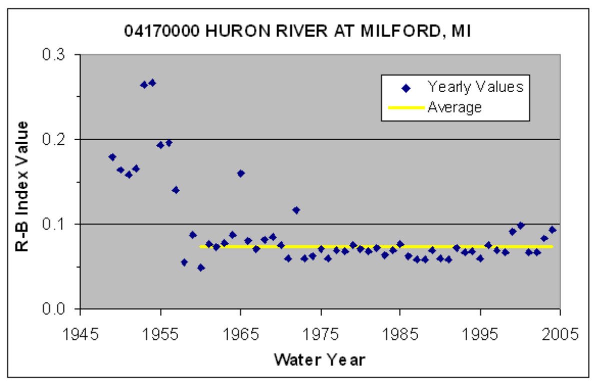
USGS Gage 04167150 – Regulation by storm water retention structures and occasional regulation by reservoirs upstream from station.



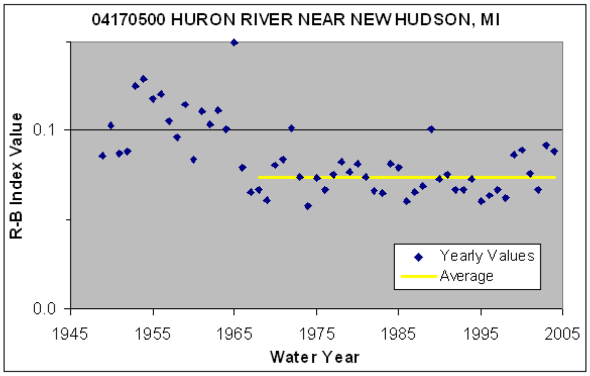
USGS Gage 04169500 – Some regulation by dams operated for lake level control of Pontiac, Oxbow, and Union Lakes.



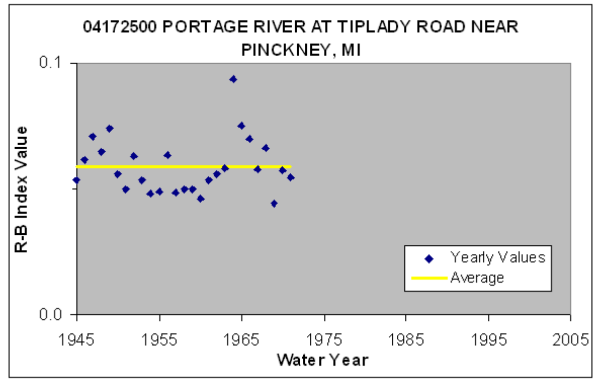
USGS Gage 04168000 – Since 1995 flow contains effluent sewage treatment plant which originates outside the basin.



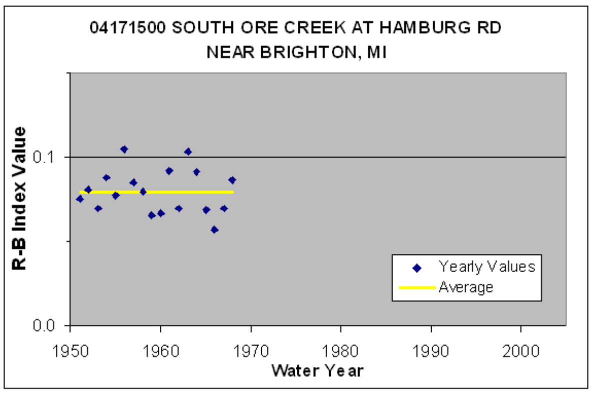
USGS Gage 04170000 – Flow regulation about 300 cubic feet per second regulated by power plant 1.5 miles upstream from station prior to May 29, 1957. Occasional regulation for lake level control since.



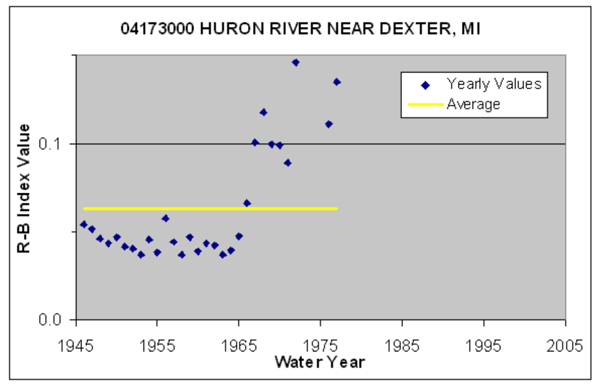
USGS Gage 04170500 – Occasional regulation by Kent Lake.



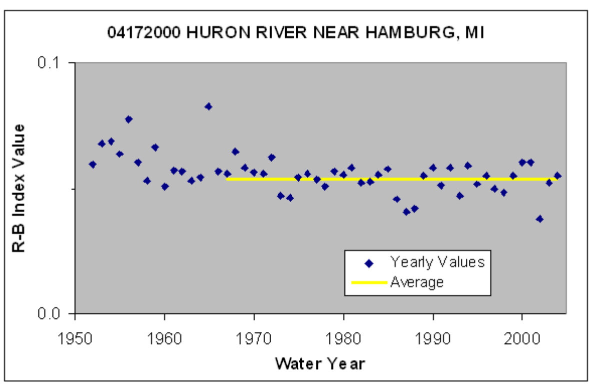
USGS Gage 04172500 – Regulation by Hiland Lake 2.5 miles above station.



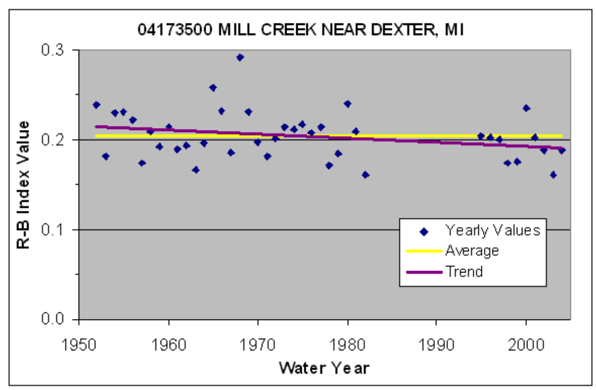
USGS Gage 04171500 – Occasional regulation by lakes above station.



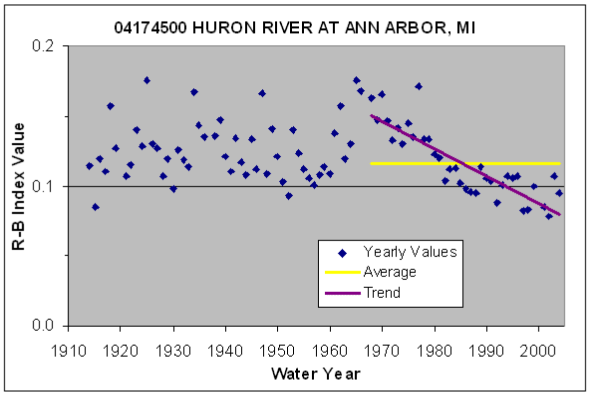
USGS Gage 04173000



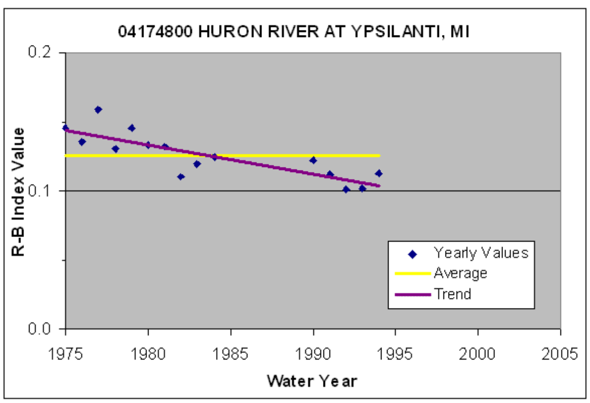
USGS Gage 04172000 – Occasional regulation by Kent Lake 11 miles upstream.



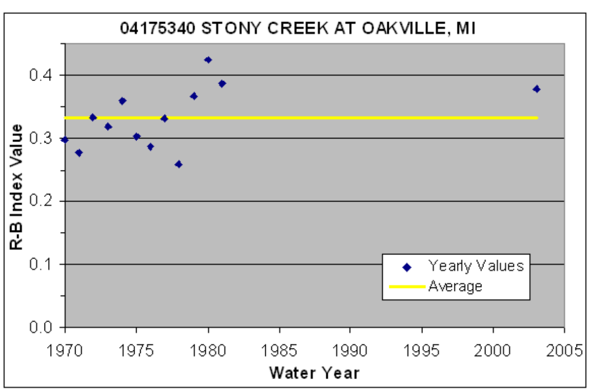
USGS Gage 04173500



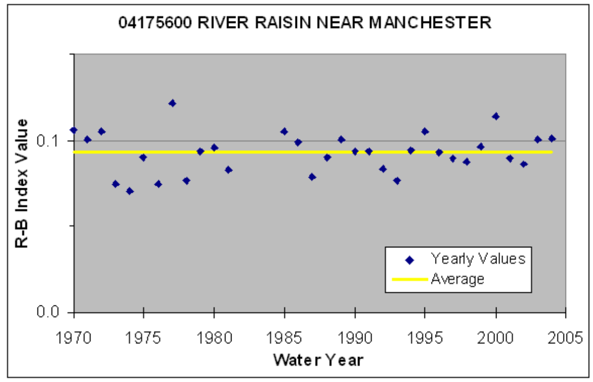
USGS Gage 04174500 – Prior to 1955 diversion upstream from station from Ann Arbor municipal supply had negligible effect on natural flow, annual mean discharge and runoff figures adjusted for diversion from 1955 to 1991. Flow regulation by power plants prior to May 1962. From June 1962 to 1975 occasional regulation for lake level control operations upstream from station. Since 1975 extensive regulation of flow exists due to automation of gates at dams upstream from station.



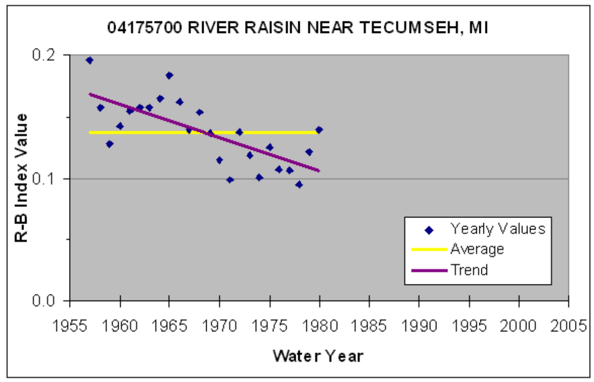
USGS Gage 04174800 – Considerable regulation caused by many dams upstream from station.



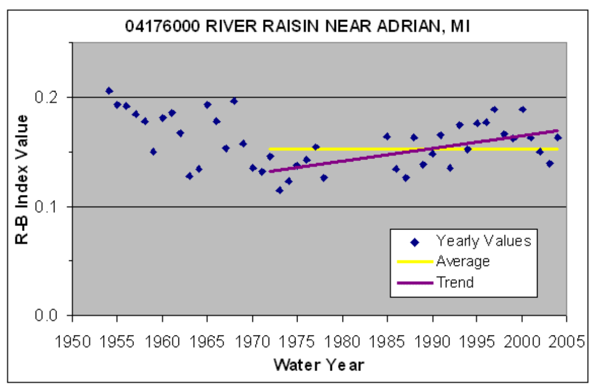
USGS Gage 04175340



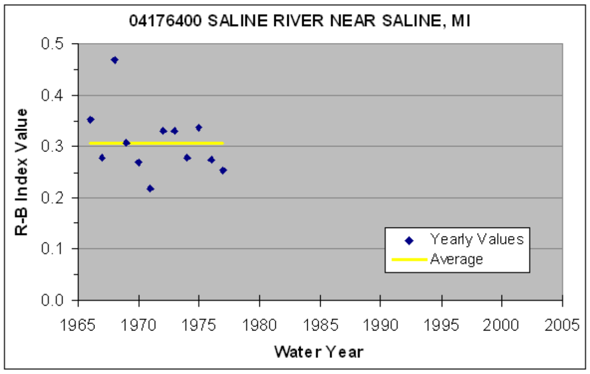
USGS Gage 04175600 – Occasional regulation caused by many dams upstream from station.



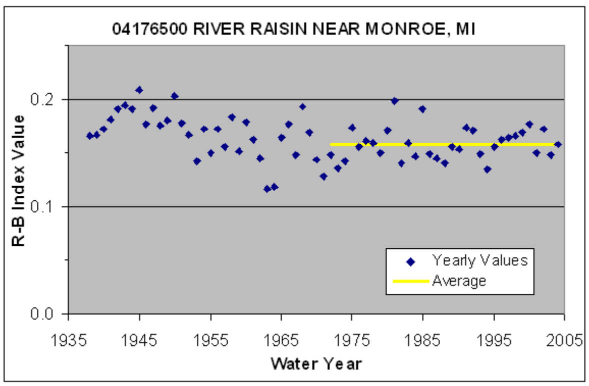
USGS Gage 04175700 – Diurnal fluctuation caused by power plant 5.5 miles above station prior to June 27, 1968.



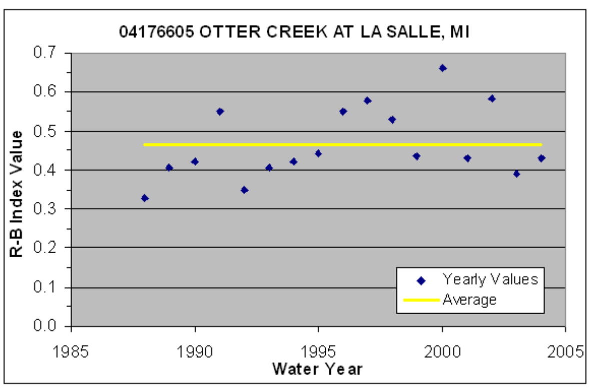
USGS Gage 04176000 – Diurnal fluctuation caused by power plant at Tecumseh, 11 miles upstream from station prior to June 27, 1968 occasional regulation since.



USGS Gage 04176400 – Slight regulation for lake level control. Pumpage for irrigation diverts an indeterminate amount of water. Saline’s sewage effluent, which originates as ground water, is included in flow.



USGS Gage 04176500 – Diurnal fluctuation caused by power plants upstream from station prior to June 27, 1968. At times flow is affected by irrigation pumpage.



USGS Gage 04176605

Appendix B: Statistical Details for Each Site

Details of the R-B flashiness statistical analysis for each gaged site are provided in Table B-1. The sites are ordered by Upper and Lower Peninsula, Great Lakes drainage, major watershed, and gage number. The table includes the watershed number, as shown on the map of Michigan's Major Watersheds, Appendix C or http://www.deq.state.mi.us/documents/deq-water-mmwsheds.pdf.

Table B-1 lists R-B Index values and related statistics as calculated for all of the data and also as calculated for a selected portion of the data for those gages where cusum analysis indicated a trend change in the data. Total Water Years may be less than the ending water year minus the starting water year because of gaps in the data. The flashiness trend in the Results table is based on the trend slopes. Statistical significance is based on the 'p' value of the regression line. A p value of 0.05 or less equates to 95 percent statistical significance. A 'p' value of 0.10 or less equates to 90 percent statistical significance.

Table B-1: R-B Flashiness Statistical Analysis Details – ordered by 1) peninsula, 2) Great Lake drainage, 3) major watershed, and 4) gage number

Major Watershed, Upper Peninsula	Watershed Number	Gage Number	Gage Description	Total Drainage Area (sq. mi.)	Average R-B Index Value	Quartile Rank	Flashiness Trend	p Value	First Water Year of Record	First Water Year Analyzed, if different	Last Water Year	Water Years Analyzed
Upper Peninsula: Lake Superior drainage												
Au Train	39	4044724	Au Train River At Forest Lake, MI	80	0.045	lowest	more flashy	<0.005	1994		2004	11
Chocolay	43	4044583	Cherry Creek Near Harvey, MI	10	0.006	lowest			1966		1981	8
Dead	45	4044400	Carp River Near Negaunee, MI	52	0.087	lowest			1962		1986	25
Montreal	51	4030000	Montreal River Near Saxon, WI	269	0.180	highest			1939		1970	32
Ontonagon	53	4033000	Middle Branch Ontonagon River Near Paulding, MI	162	0.083	lower middle	more flashy	0.01	1943	1976	2004	24
Ontonagon	53	4034500	Middle Branch Ontonagon River Near Trout Creek, MI	200	0.066	lowest	more flashy	0.02	1943	1957	2004	47
Ontonagon	53	4035000	East Branch Ontonagon River Near Mass, MI	273	0.170	upper middle			1943		1979	37
Ontonagon	53	4035500	Middle Branch Ontonagon River Near Rockland, MI	669	0.234	highest			1943		2004	62
Ontonagon	53	4036000	West Branch Ontonagon River Near Bergland, MI	163	0.099	lower middle	less flashy	<0.005	1943	1970	2004	35
Ontonagon	53	4037500	Cisco Branch Ontonagon River At Cisco Lake Outlet, MI	45	0.173	upper middle	more flashy	<0.005	1945	1978	2004	27
Ontonagon	53	4039500	South Branch Ontonagon River At Ewen, MI	345	0.145	upper middle			1942		1971	29
Ontonagon	53	4040000	Ontonagon River Near Rockland, MI	1334	0.184	highest			1943		2004	63
Portage	55	4001000	Washington Creek At Windigo, MI	13	0.225	lower middle			1965		2003	39
Portage	55	4040500	Sturgeon River Near Sidnaw, MI	169	0.153	upper middle			1913		2004	66
Portage	55	4041500	Sturgeon River Near Alston, MI	343	0.188	highest			1932		2004	71
Portage	55	4042500	Otter River Near Elo, MI	161	0.176	highest			1943		1972	30
Portage	55	4043000	Sturgeon River Near Arnheim, MI	179	0.095	lower middle			1943		1974	32

Major Watershed, Upper Peninsula	Watershed Number	Gage Number	Gage Description	Total Drainage Area (sq. mi.)	Average R-B Index Value	Quartile Rank	Flashiness Trend	p Value	First Water Year of Record	First Water Year Analyzed, if different	Last Water Year	Water Years Analyzed
Portage	55	4043050	Trap Rock River Near Lake Linden, MI	30	0.237	lower middle			1967		2004	38
Presque Isle	56	4031000	Black River Near Bessemer, MI	200	0.224	highest			1958		2004	33
Presque Isle	56	4031500	Presque Isle River at Marenisco, MI	173	0.114	upper middle			1945		1982	38
Presque Isle	56	4032000	Presque Isle River Near Tula, MI	264	0.139	upper middle			1945		1973	29
Presque Isle	56	4032500	Iron River Near White Pine, MI	97	0.448	highest			1952		1957	6
Tahquamenon	60	4045500	Tahquamenon River Near Paradise, MI	757	0.055	lowest			1954		2004	51
Upper Peninsula: Lake Michigan drainage												
Carp	41	4046000	Black River Near Garnet, MI	33	0.130	lower middle			1952		2004	37
Escanaba	46	4057800	Middle Branch Escanaba River At Humboldt, MI	46	0.169	upper middle			1960		2004	45
Escanaba	46	4057820	Middle Branch Escanaba River Near Greenwood, MI	72	0.101	lower middle			1973		1982	10
Escanaba	46	4057900	Black River Near Republic, MI	35	0.154	lower middle			1962		1968	7
Escanaba	46	4058000	Middle Branch Escanaba River Near Ishpeming, MI	128	0.132	upper middle			1955		1975	21
Escanaba	46	4058100	Middle Branch Escanaba River Near Princeton, MI	208	0.104	lower middle	less flashy	0.02	1961	1975	2004	23
Escanaba	46	4058200	Schweitzer Creek Near Palmer, MI	24	0.211	lower middle			1961		2004	44
Escanaba	46	4058300	Warner Creek Near Palmer, MI	14	0.196	lower middle			1962		1978	13
Escanaba	46	4058400	Goose Lake Outlet Near Sands Station, MI	36	0.096	lowest			1966		1982	17
Escanaba	46	4058500	East Branch Escanaba River At Gwinn, MI	125	0.133	upper middle			1955		1980	26
Escanaba	46	4059000	Escanaba River At Cornell, MI	870	0.124	upper middle	less flashy	<0.005	1951		2004	54

Major Watershed, Upper Peninsula	Watershed Number	Gage Number	Gage Description	Total Drainage Area (sq. mi.)	Average R-B Index Value	Quartile Rank	Flashiness Trend	p Value	First Water Year of Record	First Water Year Analyzed, if different	Last Water Year	Water Years Analyzed
Ford	47	4059400	Ten Mile Creek At Perronville, MI	44	0.162	upper middle			1971		1977	7
Ford	47	4059500	Ford River Near Hyde, MI	444	0.114	lower middle			1955		2004	50
Manistique	49	4049500	Manistique River at Germfask, MI	419	0.037	lowest			1938		1970	33
Manistique	49	4054500	Duck Creek Near Blaney, MI	72	0.091	lowest			1938		1954	17
Manistique	49	4055000	Manistique River Near Blaney, MI	715	0.048	lowest			1938		1970	33
Manistique	49	4056000	West Branch Manistique River Near Manistique, MI	325	0.059	lowest			1938		1956	19
Manistique	49	4056500	Manistique River Near Manistique, MI	1127	0.050	lowest			1938		2004	67
Manistique	49	4057000	Indian River Near Manistique, MI	284	0.027	lowest			1938		1993	35
Menominee	50	4060500	Iron River At Caspian, MI	93	0.097	lowest			1948		1980	33
Menominee	50	4060993	Brule River At US-2 Near Florence, WI	379	0.081	lower middle			1914		2004	61
Menominee	50	4061500	Paint River At Crystal Falls, MI	600	0.109	lower middle			1945		1996	51
Menominee	50	4062000	Paint River Near Alpha, MI	636	0.151	upper middle			1952		2004	53
Menominee	50	4062011	Brule River Near Commonwealth, WI	1041	0.135	highest	less flashy	0.02	1990		2004	15
Menominee	50	4062100	Peshekee River Near Michigamme, MI	67	0.201	upper middle			1962		1995	10
Menominee	50	4062200	Peshekee River Near Champion, MI	132	0.163	upper middle			1962		2004	21
Menominee	50	4062230	Michigamme River Near Michigamme, MI	195	0.061	lowest			1969		1982	14
Menominee	50	4062270	Michigamme River Near Champion, MI	229	0.065	lowest			1965		1969	5

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Menominee	50	4062300	Michigamme River At Republic, MI	238	0.117	upper middle			1961		1975	15
Menominee	50	4062400	Michigamme River Near Witch Lake, MI	311	0.075	lowest			1965		1980	16
Menominee	50	4062500	Michigamme River Near Crystal Falls, MI	655	0.105	lower middle	less flashy	<0.005	1945	1972	2004	33
Menominee	50	4063000	Menominee River Near Florence, WI	1778	0.122	highest			1914		2004	91
Menominee	50	4063500	Menominee River At Twin Falls Near Iron Mt, MI	1823	0.118	upper middle			1914		2004	90
Menominee	50	4065000	Menominee River Near Iron Mountain, MI	2447	0.122	highest			1903		1914	12
Menominee	50	4065300	West Branch Sturgeon River Near Randville, MI	54	0.183	upper middle			1959		1981	23
Menominee	50	4065393	East Branch Sturgeon River Below Skunk Cr Near Felch, MI	62	0.137	lower middle	less flashy	0.08	1974		1984	11
Menominee	50	4065397	East Branch Sturgeon River at Hardwood, MI	90	0.093	lowest			1978		1983	6
Menominee	50	4065500	Sturgeon River Near Foster City, MI	235	0.109	upper middle			1955		1980	26
Menominee	50	4065600	Pine Creek Near Iron Mountain, MI	16	0.156	lower middle			1972		1981	10
Menominee	50	4065722	Menominee River Near Vulcan, MI	2924	0.090	lower middle			1988		2004	17
Menominee	50	4066003	Menominee River Below Pemene Creek Near Pembine, WI	3148	0.093	lower middle	less flashy	<0.005	1950		2004	55
Menominee	50	4067000	Menominee River Below Koss, MI	3746	0.114	upper middle			1914		1981	68
Sturgeon	58	4057510	Sturgeon River Near Nahma Junction, MI	183	0.102	lower middle			1967		2004	38
Upper Peninsula: Lake Huron drainage												
Pine	54	4127918	Pine River Near Rudyard, MI	202	0.185	highest			1972		2004	33

Major Watershed, Lower Peninsula	Watershed Number	Gage Number	Gage Description	Total Drainage Area (sq. mi.)	Average R-B Index Value	Quartile Rank	Flashiness Trend	p Value	First Water Year of Record	First Water Year Analyzed, if different	Last Water Year	Water Years Analyzed
Lower Peninsula: Lake Michigan drainage												
Big Sable	5	4123000	Big Sable River Near Freesoil, MI	111	0.038	lowest			1943		1973	31
Black	7	4102700	South Branch Black River Near Bangor, MI	83	0.162	upper middle			1967		2004	38
Boardman	9	4126970	Boardman River Above Brown Bridge Rd, Near Mayfield, MI	124	0.038	lowest			1998		2004	7
Boardman	9	4127000	Boardman River Near Mayfield, MI	183	0.091	lower middle			1953		1989	37
Grand	14	4109000	Grand River At Jackson, MI	170	0.114	upper middle	less flashy	<0.005	1935	1962	2004	43
Grand	14	4109500	Portage River At Portage Lake Road Near Munith, MI	54	0.112	lower middle			1944		1956	13
Grand	14	4110000	Orchard Creek At Munith, MI	47	0.226	upper middle			1944		1956	13
Grand	14	4111000	Grand River At Eaton Rapids, MI	694	0.097	lower middle	less flashy	0.01	1951		2004	41
Grand	14	4111379	Red Cedar River Near Williamston, MI	163	0.125	upper middle			1976		2004	17
Grand	14	4111500	Deer Creek Near Dansville, MI	16	0.368	upper middle			1954		2004	51
Grand	14	4112000	Sloan Creek Near Williamston, MI	10	0.455	upper middle			1955		2004	50
Grand	14	4112500	Red Cedar River At East Lansing, MI	343	0.150	upper middle	more flashy	0.02	1931	1978	2004	27
Grand	14	4112850	Sycamore Creek Near Holt, MI	80	0.243	upper middle			1975		1997	11
Grand	14	4113000	Grand River At Lansing, MI	1246	0.114	upper middle			1901	1953	2004	52
Grand	14	4113097	Carrier Creek Near Lansing, MI	10	0.459	upper middle			1975		1980	6

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Grand	14	4114000	Grand River At Portland, MI	1397	0.122	upper middle			1953		2004	46
Grand	14	4114498	Looking Glass River Near Eagle, MI	280	0.101	lower middle			1945		2005	56
Grand	14	4115000	Maple River At Maple Rapids, MI	420	0.114	lower middle			1945		2004	61
Grand	14	4115265	Fish Creek Near Crystal, MI	70	0.174	upper middle			1988		2004	17
Grand	14	4116000	Grand River At Ionia, MI	2872	0.105	upper middle			1951	1974	2004	31
Grand	14	4116500	Flat River At Smyrna, MI	517	0.095	lower middle	less flashy	<0.005	1951		1986	36
Grand	14	4117000	Quaker Brook Near Nashville, MI	8	0.300	lower middle			1955		2004	31
Grand	14	4117500	Thornapple River Near Hastings, MI	410	0.107	lower middle			1945	1962	2004	43
Grand	14	4118000	Thornapple River Near Caledonia, MI	795	0.095	lower middle	more flashy	<0.005	1952	1971	1994	24
Grand	14	4118500	Rogue River Near Rockford, MI	257	0.100	lower middle			1952	1979	2003	20
Grand	14	4119000	Grand River At Grand Rapids, MI	4903	0.073	lowest			1901	1978	2004	27
Kalamazoo	17	4102850	South Branch Kalamazoo River Near Albion, MI	148	0.059	lowest			1972		1976	5
Kalamazoo	17	4103010	Kalamazoo River Near Marengo, MI	270	0.061	lowest			1987		2004	18
Kalamazoo	17	4103500	Kalamazoo River at Marshall, MI	411	0.145	upper middle			1949		2004	37
Kalamazoo	17	4104945	Wanadoga Creek Near Battle Creek, MI	48	0.152	lower middle			1995		2004	10
Kalamazoo	17	4105000	Battle Creek At Battle Creek, MI	274	0.101	lower middle	more flashy	<0.005	1935	1963	2004	42
Kalamazoo	17	4105500	Kalamazoo River Near Battle Creek, MI	819	0.090	lower middle	less flashy	<0.005	1938		2004	67

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Kalamazoo	17	4105700	Augusta Creek Near Augusta, MI	37	0.081	lowest	more flashy	0.04	1965		2004	40
Kalamazoo	17	4105800	Gull Creek Near Galesburg, MI	36	0.060	lowest			1965		1972	8
Kalamazoo	17	4106000	Kalamazoo River At Comstock, MI	1059	0.078	lower middle			1933	1963	2004	37
Kalamazoo	17	4106180	Portage Creek At Portage, MI	15	0.077	lowest	more flashy	0.02	1983		2004	22
Kalamazoo	17	4106300	Portage Creek Near Kalamazoo, MI	20	0.107	lowest			1965	1988	2003	16
Kalamazoo	17	4106320	West Fork Portage Creek Near Oshtemo, MI	15	0.064	lowest	more flashy	<0.005	1973		1996	24
Kalamazoo	17	4106400	West Fork Portage Creek At Kalamazoo, MI	21	0.077	lowest	more flashy	<0.005	1960	1975	2004	30
Kalamazoo	17	4106500	Portage Creek At Kalamazoo, MI	48	0.107	lower middle	more flashy	0.01	1948		1986	23
Kalamazoo	17	4108500	Kalamazoo River Near Fennville, MI	1653	0.108	upper middle			1929		1993	64
Kalamazoo	17	4108600	Rabbit River Near Hopkins, MI	65	0.209	upper middle	more flashy	0.01	1966		2003	38
Macatawa	7	4102776	Middle Branch Black River Near South Haven, MI	83	0.124	lower middle			1995		2004	10
Macatawa	8	4108801	Macatawa River Near Zeeland, MI	69	0.573	highest			1961		2005	45
Manistee	20	4123500	Manistee River Near Grayling, MI	132	0.026	lowest			1943		1973	31
Manistee	20	4124000	Manistee River Near Sherman, MI	865	0.035	lowest			1903		2004	84
Manistee	20	4124200	Manistee River Near Mesick, MI	981	0.042	lowest			1997		2004	9
Manistee	20	4124500	East Branch Pine River Near Tustin, MI	59	0.193	upper middle			1953		2004	24
Manistee	20	4125000	Pine River Near Leroy, MI	130	0.137	upper middle			1953		1963	11

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Manistee	20	4125460	Pine River at High School Bridge, Near Hoxeyville, MI	249	0.065	lowest			1953		2004	38
Manistee	20	4125550	Manistee River Near Wellston, MI	1379	0.049	lowest			1997		2004	8
Manistee	20	4126000	Manistee River Near Manistee, MI	1684	0.095	lower middle	less flashy	<0.005	1952	1983	1993	11
Manistee	20	4126200	Little Manistee River Near Freesoil, MI	185	0.037	lowest			1957		1975	19
Muskegon	22	4121000	Muskegon River Near Merritt, MI	352	0.050	lowest			1947		1973	27
Muskegon	22	4121300	Clam River At Vogel Center, MI	239	0.078	lower middle			1967		2004	38
Muskegon	22	4121500	Muskegon River At Evart, MI	1431	0.057	lowest			1934	1960	2004	46
Muskegon	22	4121900	Little Muskegon River Near Morley, MI	135	0.104	lower middle	more flashy	0.07	1967		1996	30
Muskegon	22	4121944	Little Muskegon River Near Oak Grove, MI	363	0.087	lower middle			1996		2004	9
Muskegon	22	4121970	Muskegon River Near Croton, MI	2325	0.061	lowest			1996		2004	9
Muskegon	22	4122000	Muskegon River At Newaygo, MI	2399	0.111	upper middle	less flashy	0.06	1910		1993	72
Muskegon	22	4122100	Bear Creek Near Muskegon, MI	17	0.206	lower middle	less flashy	<0.005	1966		2003	38
Pere Marquette	25	4122500	Pere Marquette River At Scottville, MI	689	0.044	lowest	more flashy	<0.005	1940		2004	67
Pine	10	4127800	Jordan River Near East Jordan, MI	67	0.068	lowest	less flashy	0.04	1967	1984	2004	21
Platte	28	4126740	Platte River At Honor, MI	125	0.042	lowest			1990		2004	15
St. Joseph	34	4096015	Galien River Near Sawyer, MI	81	0.293	upper middle	less flashy	0.03	1996		2004	9
St. Joseph	34	4096272	Beebe Creek Near Hillsdale, MI	43	0.164	upper middle			1974		1981	8

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St. Joseph	34	4096405	St. Joseph River At Burlington, MI	197	0.062	lowest			1963		2004	42
St. Joseph	34	4096500	Sauk River at Jay St at Coldwater, MI	56	0.100	lowest			1938		1962	25
St. Joseph	34	4096515	South Branch Hog Creek Near Allen, MI	49	0.119	lower middle	more flashy	<0.005	1970		2004	36
St. Joseph	34	4096600	Coldwater River Near Hodunk, MI	287	0.078	lower middle			1963		1989	27
St. Joseph	34	4096900	Nottawa Creek Near Athens, MI	151	0.077	lower middle	more flashy	0.02	1967		1997	31
St. Joseph	34	4097170	Portage River Near Vicksburg, MI	66	0.050	lowest			1946		1979	21
St. Joseph	34	4097200	Gourdneck Creek Near Schoolcraft, MI	8	0.094	lowest			1964		1972	9
St. Joseph	34	4097500	St. Joseph River At Three Rivers, MI	1347	0.087	lower middle	less flashy	0.01	1953		2004	43
St. Joseph	34	4097540	Prairie River Near Nottawa, MI	107	0.055	lowest			1963		2004	42
St. Joseph	34	4098500	Fawn River Near White Pigeon, MI	203	0.051	lowest			1958		1975	18
St. Joseph	34	4099000	St. Joseph River At Mottville, MI	1879	0.100	upper middle	less flashy	<0.005	1924		2004	81
St. Joseph	34	4101500	St. Joseph River At Niles, MI	3715	0.086	lower middle	less flashy	<0.005	1931		2004	73
St. Joseph	34	4101800	Dowagiac River At Sumnerville, MI	252	0.081	lower middle	more flashy	0.01	1961	1973	2004	32
St. Joseph	34	4102000	St. Joseph River At Berrien Springs, MI	4086	0.085	lower middle			1901		1956	12
St. Joseph	34	4102500	Paw Paw River At Riverside, MI	390	0.054	lowest	more flashy	<0.005	1952	1971	2004	34
White	37	4122200	White River Near Whitehall, MI	405	0.064	lowest			1957		2003	47
Lower Peninsula: Lake Huron drainage, includes streams tributary to the St. Clair River, Lake St. Clair, and Detroit River												
Au Gres	1	4138000	East Branch Au Gres River At McIvor, MI	90	0.137	lower middle			1951		1973	23

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Au Gres	1	4138500	Au Gres River Near National City, MI	151	0.223	highest			1951		1981	31
Au Sable	2	4135500	Au Sable River At Grayling, MI	97	0.043	lowest	more flashy	<0.005	1943	1956	1993	38
Au Sable	2	4135600	East Branch Au Sable River At Grayling, MI	71	0.048	lowest	more flashy	0.09	1958		1984	28
Au Sable	2	4135700	South Branch Au Sable River Near Luzerne, MI	391	0.043	lowest			1967		2004	37
Au Sable	2	4136000	Au Sable River Near Red Oak, MI	1108	0.046	lowest			1909		2004	15
Au Sable	2	4136500	Au Sable River At Mio, MI	1360	0.070	lowest			1953	1980	2004	25
Au Sable	2	4136900	Au Sable River Near Mc Kinley, MI	1512	0.046	lowest			1997		2004	8
Au Sable	2	4137005	Au Sable River Near Curtisville, MI	1597	0.050	lowest			1997		2005	9
Au Sable	2	4137500	Au Sable River Near Au Sable, MI	1739	0.099	lower middle	less flashy	<0.005	1988		2004	18
Belle	3	4160570	North Branch Belle River At Imlay City, MI	16	0.294	lower middle			1966		2001	36
Belle	3	4160600	Belle River At Memphis, MI	151	0.305	highest	more flashy	0.01	1963		2004	42
Black	6	4159492	Black River Near Jeddo, MI	462	0.376	highest	more flashy	<0.005	1944	1972	2004	33
Black	6	4159500	Black River Near Fargo, MI	479	0.335	highest			1944	1963	1991	29
Black	6	4159900	Mill Creek Near Avoca, MI	169	0.275	highest			1963		2004	30
Black	6	4160000	Mill Creek Near Abbottsford, MI	184	0.255	highest			1948		1964	17
Black	6	4160050	Black River Near Port Huron, MI	682	0.323	highest			1933		1943	11
Cheboygan	11	4127997	Sturgeon River At Wolverine, MI	175	0.078	lower middle			1943	1973	2004	32
Cheboygan	11	4128990	Pigeon River Near Vanderbilt, MI	59	0.133	lower middle	more flashy	<0.005	1951		2004	54
Cheboygan	11	4129500	Pigeon River At Afton, MI	144	0.093	lower middle			1942		1981	40

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Cheboygan	11	4130000	Cheboygan River Near Cheboygan, MI	876	0.064	lowest			1943		1982	40
Cheboygan	11	4130500	Black River Near Tower, MI	302	0.142	upper middle			1943		2000	57
Cheboygan	11	4131000	Rainy River Near Onaway, MI	85	0.133	lower middle			1942		1952	11
Cheboygan	11	4131500	Rainy River Near Ocqueoc, MI	96	0.134	lower middle			1953		1979	27
Cheboygan	11	4132000	Black River Near Cheboygan, MI	556	0.146	upper middle			1943		1974	32
Clinton	12	4160800	Sashabaw Creek Near Drayton Plains, MI	21	0.134	lowest			1960		2004	45
Clinton	12	4160900	Clinton River Near Drayton Plains, MI	78	0.076	lowest			1960	1981	2004	24
Clinton	12	4161000	Clinton River At Auburn Heights, MI	123	0.140	upper middle	more flashy	<0.005	1936		2004	33
Clinton	12	4161100	Galloway Creek Near Auburn Heights, MI	17	0.314	upper middle	more flashy	<0.005	1960	1972	1991	20
Clinton	12	4161500	Paint Creek Near Lake Orion, MI	40	0.119	lower middle			1956		1991	23
Clinton	12	4161540	Paint Creek At Rochester, MI	72	0.158	lower middle	more flashy	<0.005	1960		2004	45
Clinton	12	4161580	Stony Creek Near Romeo, MI	24	0.170	lower middle	more flashy	<0.005	1965	1984	2004	21
Clinton	12	4161800	Stony Creek Near Washington, MI	69	0.128	lower middle			1958	1963	2004	42
Clinton	12	4161820	Clinton River at Sterling Heights, MI	310	0.172	highest			1979		2004	10
Clinton	12	4162010	Red Run Near Warren, MI	34	1.009	highest			1980		1988	9
Clinton	12	4162900	Big Beaver Creek Near Warren, MI	21	0.848	highest	more flashy	<0.005	1959	1971	1988	18
Clinton	12	4163400	Plum Brook At Utica, MI	17	0.541	highest			1966		2004	37
Clinton	12	4163500	Plum Brook Near Utica, MI	24	0.497	highest			1954		1966	13

Major Watershed, Lower Peninsula	Watershed Number	Gage Number	Gage Description	Total Drainage Area (sq. mi.)	Average R-B Index Value	Quartile Rank	Flashiness Trend	p Value	First Water Year of Record	First Water Year Analyzed, if different	Last Water Year	Water Years Analyzed
Clinton	12	4164000	Clinton River Near Fraser, MI	425	0.255	highest	more flashy	<0.005	1948		2004	58
Clinton	12	4164010	North Branch Clinton River at Almont, MI	10	0.420	upper middle			1963		1968	6
Clinton	12	4164050	North Branch Clinton River Near Romeo, MI	50	0.412	highest			1965		1969	5
Clinton	12	4164100	East Pond Creek At Romeo, MI	21	0.155	lowest			1958	1966	2004	39
Clinton	12	4164150	North Branch Clinton River Near Meade, MI	89	0.325	highest			1968		1972	5
Clinton	12	4164200	Coon Creek Near Armada, MI	9	0.489	upper middle			1966		1970	5
Clinton	12	4164250	Tupper Brook at Ray Center, MI	9	0.669	highest			1960		1964	5
Clinton	12	4164300	East Branch Coon Creek At Armada, MI	13	0.631	highest			1959		2004	46
Clinton	12	4164350	Highbank Creek Near Armada, MI	15	0.680	highest			1965		1970	7
Clinton	12	4164360	East Branch Cook Creek at 29-Mile Rd Near New Haven, MI	37	0.539	highest			1968		1972	5
Clinton	12	4164400	Deer Creek at Meade, MI	13	0.760	highest			1961		1965	5
Clinton	12	4164450	McBride Drain Near Macomb, MI	6	0.682	highest			1960		1964	5
Clinton	12	4164500	North Branch Clinton River Near Mount Clemens, MI	198	0.346	highest	more flashy	0.03	1948	1972	2004	34
Clinton	12	4164600	Middle Branch Clinton River At Schoenherr Rd Near Macomb, MI	22	0.441	upper middle			1965		1969	5
Clinton	12	4164800	Middle Branch Clinton River At Macomb, MI	41	0.439	highest			1963		1982	19
Clinton	12	4165200	Gloede Ditch Near Waldenburg, MI	16	0.461	upper middle			1960		1964	5
Clinton	12	4165500	Clinton River At Mount Clemens, MI	713	0.262	highest	more flashy	<0.005	1934	1971	2004	34

Major Watershed, Lower Peninsula	Watershed Number	Gage Number	Gage Description	Total Drainage Area (sq. mi.)	Average R-B Index Value	Quartile Rank	Flashiness Trend	p Value	First Water Year of Record	First Water Year Analyzed, if different	Last Water Year	Water Years Analyzed
Kawkawlin	18	4143500	North Branch Kawkawlin River Near Kawkawlin, MI	103	0.205	highest	less flashy	0.01	1952		1982	31
Pigeon	26	4158500	Pigeon River Near Owendale, MI	53	0.390	highest			1953		1982	29
Pigeon	26	4159010	Pigeon River Near Caseville, MI	127	0.375	highest			1987		1993	7
Rifle	30	4139000	Houghton Creek Near Lupton, MI	30	0.126	lowest			1951		1973	24
Rifle	30	4139500	Rifle River At "The Ranch" Near Lupton, MI	57	0.101	lower middle			1951		1971	21
Rifle	30	4140000	Prior Creek Near Selkirk, MI	21	0.237	lower middle			1951		1972	22
Rifle	30	4140500	Rifle River At Selkirk, MI	116	0.122	upper middle	less flashy	0.02	1951		1982	32
Rifle	30	4141000	South Branch Shepards Creek Near Selkirk, MI	1	0.627	highest			1952		1978	27
Rifle	30	4141500	West Branch Rifle River Near Selkirk, MI	65	0.184	upper middle			1952		1963	12
Rifle	30	4142000	Rifle River Near Sterling, MI	333	0.142	upper middle			1937		2004	68
Rouge	31	4166000	River Rouge At Birmingham, MI	37	0.373	highest	more flashy	<0.005	1950		2004	54
Rouge	31	4166100	River Rouge At Southfield, MI	87	0.456	highest	more flashy	0.02	1958		2004	47
Rouge	31	4166200	Evans Ditch At Southfield, MI	10	0.846	highest	more flashy	<0.005	1959		2003	45
Rouge	31	4166300	Upper River Rouge At Farmington, MI	18	0.403	upper middle	more flashy	<0.005	1958		2004	47
Rouge	31	4166470	Upper River Rouge at Detroit, MI	69	0.553	highest			1998		2004	7
Rouge	31	4166500	River Rouge At Detroit, MI	184	0.433	highest	more flashy	<0.005	1931		2004	67
Rouge	31	4167000	Middle River Rouge Near Garden City, MI	99	0.350	highest	more flashy	<0.005	1931		2004	54
Rouge	31	4167150	Middle River Rouge at Dearborn, MI	110	0.407	highest			1998		2004	7

Major Watershed, Lower Peninsula	Watershed Number	Gage Number	Gage Description	Total Drainage Area (sq. mi.)	Average R-B Index Value	Quartile Rank	Flashiness Trend	p Value	First Water Year of Record	First Water Year Analyzed, if different	Last Water Year	Water Years Analyzed
Rouge	31	4168000	Lower River Rouge At Inkster, MI	84	0.522	highest	less flashy	<0.005	1947		2004	58
Rouge	31	4168400	Lower River Rouge At Dearborn, MI	91	0.370	highest			1998		2004	7
Saginaw	32	4143900	Shiawassee River At Linden, MI	82	0.071	lowest			1968		2003	32
Saginaw	32	4144000	Shiawassee River At Byron, MI	364	0.110	lower middle	less flashy	<0.005	1948		1983	36
Saginaw	32	4144500	Shiawassee River At Owosso, MI	531	0.126	upper middle			1931	1953	2004	52
Saginaw	32	4145000	Shiawassee River Near Fergus, MI	622	0.134	upper middle			1940	1953	2004	42
Saginaw	32	4145500	Bad River Near Brant, MI	90	0.427	highest			1949		1959	11
Saginaw	32	4146000	Farmers Creek Near Lapeer, MI	51	0.126	lower middle			1933	1971	2004	34
Saginaw	32	4146063	South Branch Flint River Near Columbiaville, MI	211	0.135	upper middle			1980		2004	25
Saginaw	32	4147500	Flint River Near Otisville, MI	526	0.121	upper middle	more flashy	0.08	1953		2004	51
Saginaw	32	4147990	Butternut Creek Near Genesee, MI	35	0.282	upper middle			1970		1983	14
Saginaw	32	4148000	Flint River at Genesee, MI	593	0.126	upper middle			1931		1952	22
Saginaw	32	4148140	Kearsley Creek Near Davison, MI	100	0.178	upper middle			1966	1978	2004	27
Saginaw	32	4148160	Gilkey Creek near Flint, MI	7	0.694	highest			1970		1983	14
Saginaw	32	4148200	Swartz Creek Near Holly, MI	12	0.140	lowest			1956		1975	20
Saginaw	32	4148300	Swartz Creek At Flint, MI	114	0.284	highest			1970		1983	14
Saginaw	32	4148440	Thread Creek Near Flint, MI	56	0.217	upper middle			1970		1983	14
Saginaw	32	4148500	Flint River Near Flint, MI	960	0.163	highest	more flashy	0.03	1933	1978	2004	27
Saginaw	32	4148720	Brent Run Near Montrose, MI	21	0.478	upper middle			1970		1983	14

Major Watershed, Lower Peninsula	Watershed Number	Gage Number	Gage Description	Total Drainage Area (sq. mi.)	Average R-B Index Value	Quartile Rank	Flashiness Trend	p Value	First Water Year of Record	First Water Year Analyzed, if different	Last Water Year	Water Years Analyzed
Saginaw	32	4149000	Flint River Near Fosters, MI	1153	0.168	highest	less flashy	0.05	1940		2004	54
Saginaw	32	4150000	South Branch Cass River Near Cass City, MI	239	0.397	highest			1949		1980	32
Saginaw	32	4150500	Cass River At Cass City, MI	362	0.331	highest			1948	1968	2004	34
Saginaw	32	4150800	Cass River At Wahjamega, MI	646	0.275	highest			1969		1994	26
Saginaw	32	4151000	Cass River At Vassar, MI	710	0.266	highest			1949		1970	22
Saginaw	32	4151500	Cass River At Frankenmuth, MI	842	0.242	highest			1908	1962	2004	43
Saginaw	32	4152238	South Branch Tobacco River Near Beaverton, MI	152	0.172	highest			1987		2004	18
Saginaw	32	4152500	Tobacco River At Beaverton, MI	426	0.205	highest	less flashy	<0.005	1949		1982	34
Saginaw	32	4153500	Salt River Near North Bradley, MI	145	0.402	highest			1935		1971	37
Saginaw	32	4154000	Chippewa River Near Mount Pleasant, MI	409	0.089	lower middle			1934	1962	2004	40
Saginaw	32	4154500	Chippewa River Near Midland, MI	594	0.144	upper middle			1948		1972	25
Saginaw	32	4155000	Pine River At Alma, MI	309	0.116	upper middle			1931	1960	2004	45
Saginaw	32	4155500	Pine River Near Midland, MI	408	0.196	highest			1935	1980	2004	23
Saginaw	32	4156000	Tittabawassee River At Midland, MI	2371	0.228	highest			1936		2004	69
Saginaw	32	4156500	Tittabawassee River at Freeland, MI	2435	0.189	highest			1931		1936	6
Sebewaing	33	4157500	Sebewaing River State Drain Near Sebewaing, MI	64	0.630	highest			1940		1954	15
Sebewaing	33	4158000	Columbia Drain Near Sebewaing, MI	33	0.643	highest			1940		1990	18
Thunder Bay	36	4132500	Thunder Bay River Near Hillman, MI	221	0.082	lower middle			1946		1972	27
Thunder Bay	36	4133501	Thunder Bay River Near Bolton, MI	586	0.083	lower middle			1945		2005	39

Major Watershed, Lower Peninsula	Watershed Number	Gage Number	Gage Description	Total Drainage Area (sq. mi.)	Average R-B Index Value	Quartile Rank	Flashiness Trend	p Value	First Water Year of Record	First Water Year Analyzed, if different	Last Water Year	Water Years Analyzed
Thunder Bay	36	4134000	North Branch Thunder Bay River Near Bolton, MI	174	0.143	upper middle			1945		1980	36
Thunder Bay	36	4135000	Thunder Bay River Near Alpena, MI	1237	0.191	highest			1901		1993	22
Lower Peninsula: Lake Erie drainage												
Huron	15	4169500	Huron River At Commerce, MI	50	0.054	lowest			1946		1975	30
Huron	15	4170000	Huron River At Milford, MI	139	0.074	lowest			1949	1960	2004	45
Huron	15	4170500	Huron River Near New Hudson, MI	155	0.074	lowest			1949	1968	2004	37
Huron	15	4171500	South Ore Creek Near Brighton, MI	33	0.080	lowest			1951		1968	18
Huron	15	4172000	Huron River Near Hamburg, MI	320	0.053	lowest			1952	1967	2004	38
Huron	15	4172500	Portage River Near Pinckney, MI	82	0.059	lowest			1945		1971	27
Huron	15	4173000	Huron River Near Dexter, MI	537	0.064	lowest			1946		1977	29
Huron	15	4173500	Mill Creek Near Dexter, MI	131	0.204	highest	less flashy	0.09	1952		2004	41
Huron	15	4174500	Huron River At Ann Arbor, MI	747	0.116	lower middle	less flashy	<0.005	1914	1968	2004	36
Huron	15	4174800	Huron River At Ypsilanti, MI	817	0.125	upper middle	less flashy	<0.005	1975		1994	15
Raisin	29	4175600	River Raisin Near Manchester, MI	132	0.093	lower middle			1970		2004	32
Raisin	29	4175700	River Raisin Near Tecumseh, MI	270	0.137	upper middle	less flashy	<0.005	1957		1980	24
Raisin	29	4176000	River Raisin Near Adrian, MI	478	0.153	upper middle	more flashy	<0.005	1954	1972	2004	27
Raisin	29	4176400	Saline River Near Saline, MI	94	0.308	upper middle			1966		1977	12
Raisin	29	4176500	River Raisin Near Monroe, MI	1040	0.158	highest			1938	1972	2004	33
Raisin	29	4176605	Otter Creek At Lasalle, MI	64	0.465	highest			1988		2004	17
Stony Creek	35	4175340	Stony Creek At Oakville, MI	69	0.332	highest			1970		2003	13

Land and Water Management Division

Appendix C: Michigan's Major Watersheds

1 Au Gres
1A E. Br. Au Gres
2 Au Sable
2A Pine
3 Belle
4 Betsie
5 Big Sable
6 Black
7 Black
8 Macatawa
9 Boardman
10 Pine
10A Boyne
10B Jordan
11 Cheboygan
12 Clinton
13 Elk
14 Grand
14A Red Cedar
14B Looking Glass
14C Maple
14D Thornapple
14E Flat
14F Rogue
15 Huron
17 Kalamazoo
18 Kawkawlin
19 Lincoln
20 Manistee
21 Maumee
22 Muskegon
23 Ocqueoc
24 Pentwater
25 Pere Marquette
26 Pigeon
27 Pine
28 Platte
29 Raisin
30 Rifle
31 Rouge
32 Saginaw
32A Cass
32B Flint
32C Shiawassee
32D Tittabawassee
32E Chippewa
33 Sebewaing
34 St. Joseph
34A Paw Paw
34B Pigeon
34C Elkhart
35 Stony Creek
36 Thunder Bay
37 White
38 Willow
39 Au Train
40 Black
41 Carp
42 Cedar
43 Chocolay
44 Days
45 Dead
46 Escanaba
47 Ford
48 Falls
49 Manistique
50 Menominee
50A Paint
50B Brule
50C Michigamme
50D Pine
50E Sturgeon
51 Montreal
52 Munuscong
53 Ontonagon
54 Pine
55 Portage
55A Sturgeon
56 Presque Isle
57 Rapid
58 Sturgeon
60 Tahquamenon
61 Two Hearted
62 Waiska
63 Whitefish

Note: Basin Numbers containing an "L" represent Lake Drainage

Appendix D: Explanation of Cusum Analysis

Visual examination of the gage data plots indicates that some gages have experienced trend changes. To identify where the trend change occurs, a cumulative sum statistical technique, termed cusum, was then applied to the data. For each gage in question, the differences between the yearly R-B Index value and the overall average R-B Index value were cumulatively summed, as shown in Table D1 and Figure D1. Cusum curve inflection points, rather than extremes, indicate the timing of trend changes, as shown in Figures D2 and D3. Taking the first derivative of the cusum curve therefore helps identify trend change points.

In order to eliminate some of the annual variability associated with actual gage data, the first derivative of a five-year moving average of the cusum data was used for the flashiness analysis. Example graphs from trend analyses for two gages are shown in Figures D4 through D7. Gage 04127997 has a statistically significant increasing trend when evaluating all of the data, but no trend when performing a regression analysis on the data since 1973, Figures D4 and D5. Gage 04165500 has no statistically significant trend when evaluating all of the data, but a statistically significant increasing trend when performing a regression analysis on the 1972 to 2004 data, Figures D6 and D7. Both break points are extremes on the first derivative cusum plots. All 57 gages that have identified trend changes are listed in Tables 2 and 3 of the report.

Table D1 – Sample Data and Cusum Calculation

Year	R-B Index Value	Average	Difference	Cusum
1995	0.115	0.100	0.015	0.015
1996	0.115	0.100	0.015	0.030
1997	0.100	0.100	0.000	0.030
1998	0.100	0.100	0.000	0.030
1999	0.100	0.100	0.000	0.030
2000	0.115	0.100	0.015	0.045
2001	0.092	0.100	-0.008	0.037
2002	0.068	0.100	-0.032	0.005
2003	0.085	0.100	-0.015	-0.010
2004	0.110	0.100	0.010	0.000

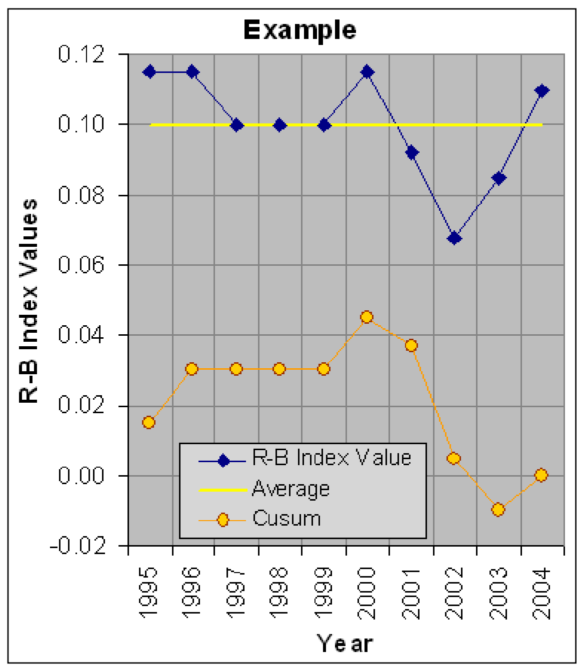

Figure D1 –Sample Data and Cusum Plots

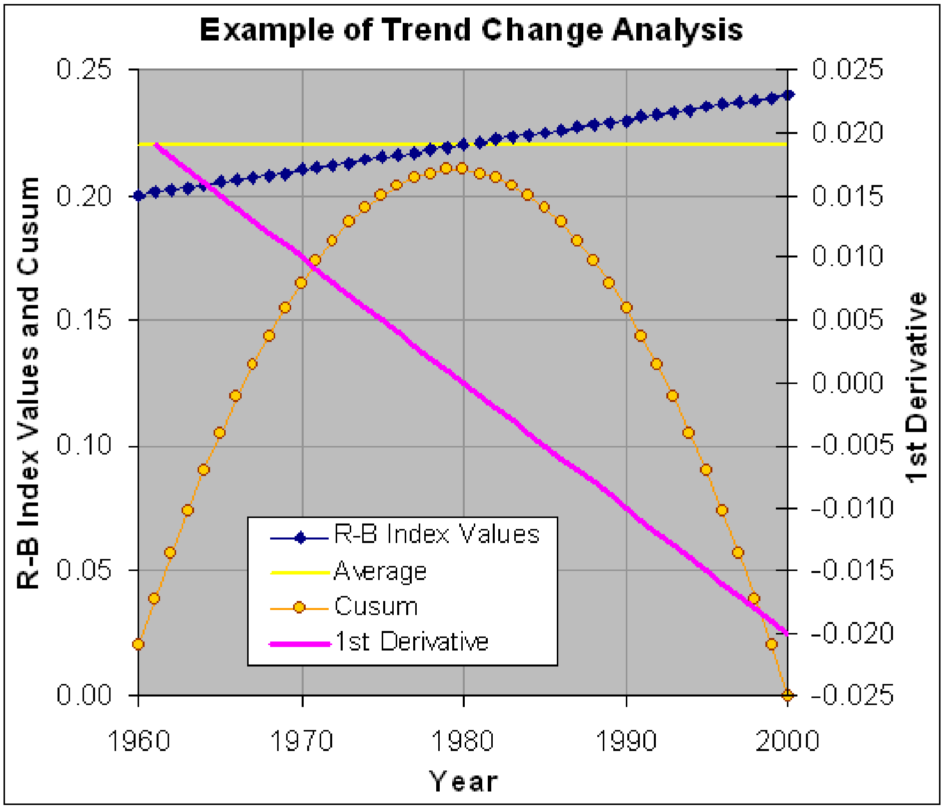

Figure D2 – Example of Cusum Analysis showing no trend change

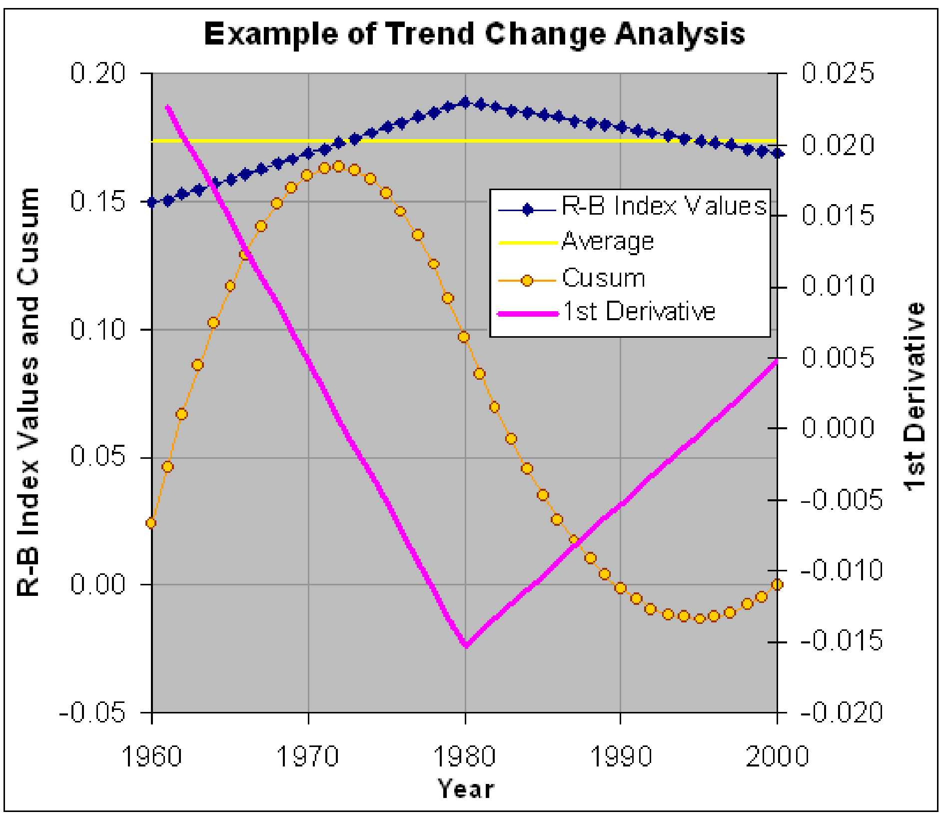

Figure D3 – Example of Cusum Analysis showing trend change at 1980

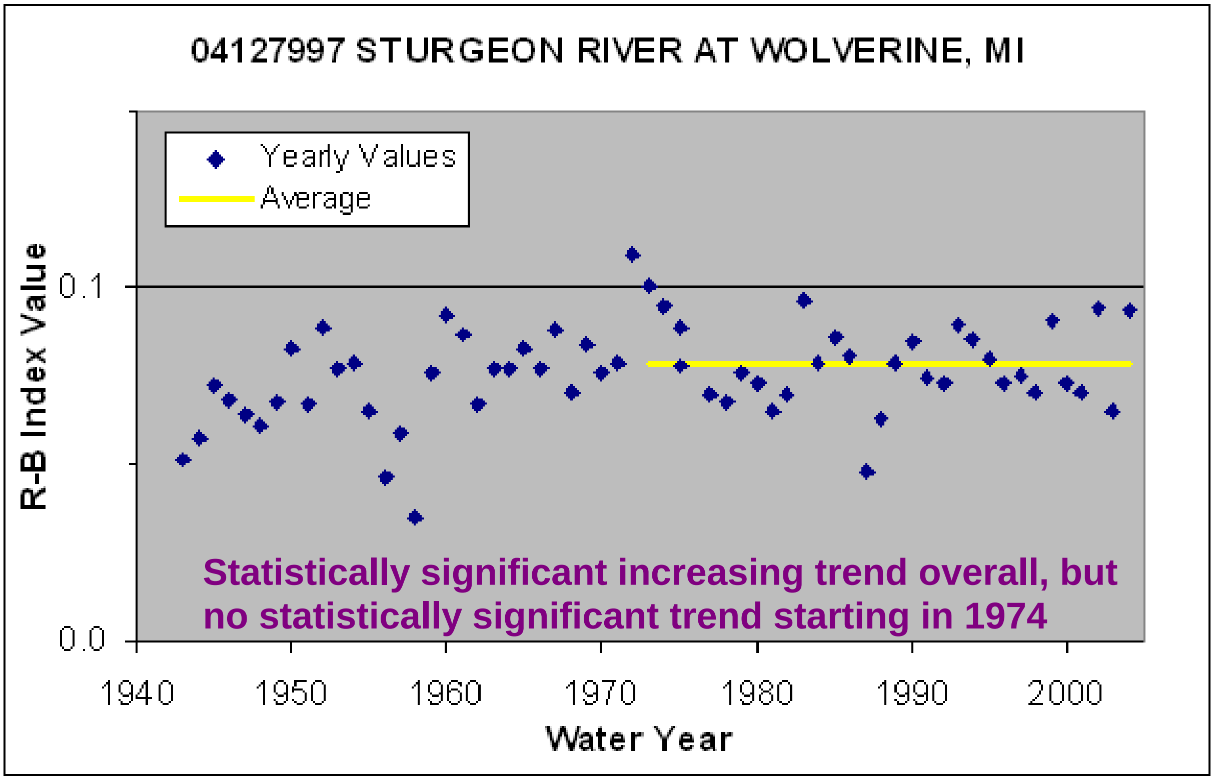

Figure D4 – USGS Gage 04127997 R-B Index Values

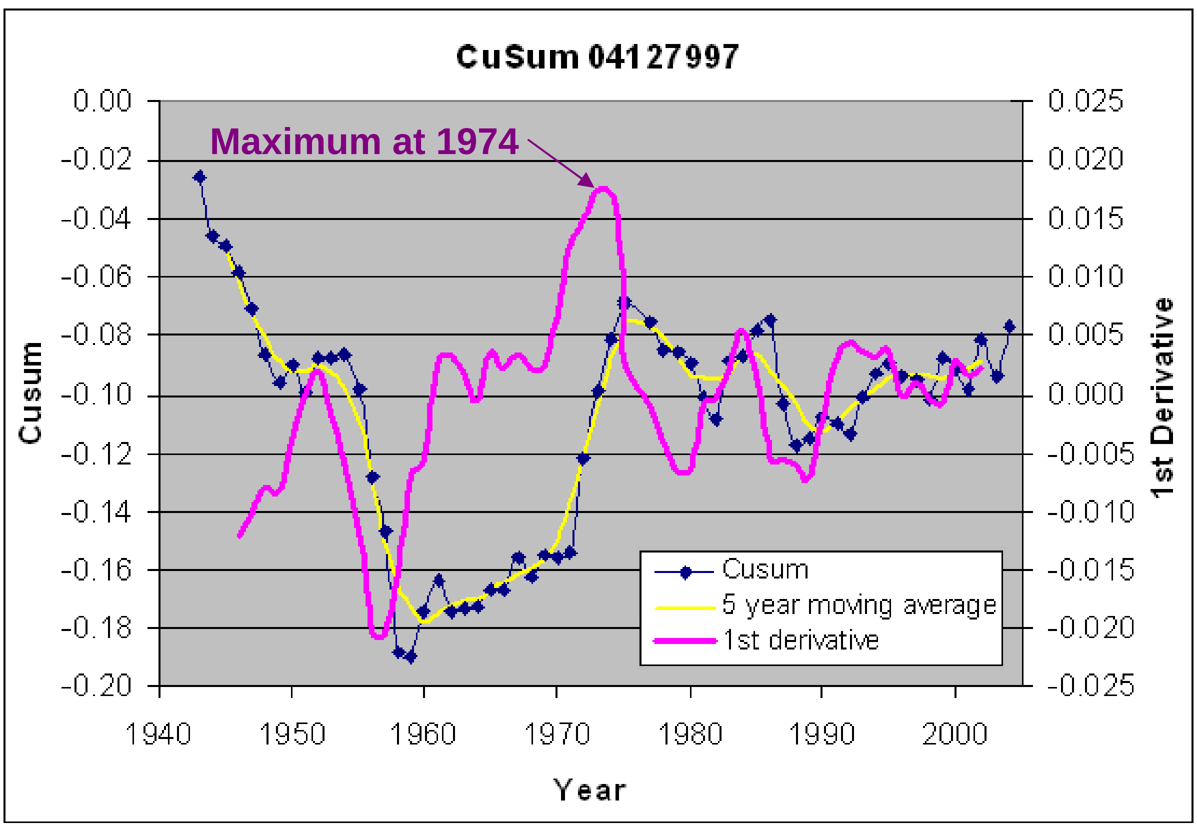

Figure D5 – Cusum analysis, defining potential breakpoint at 1974

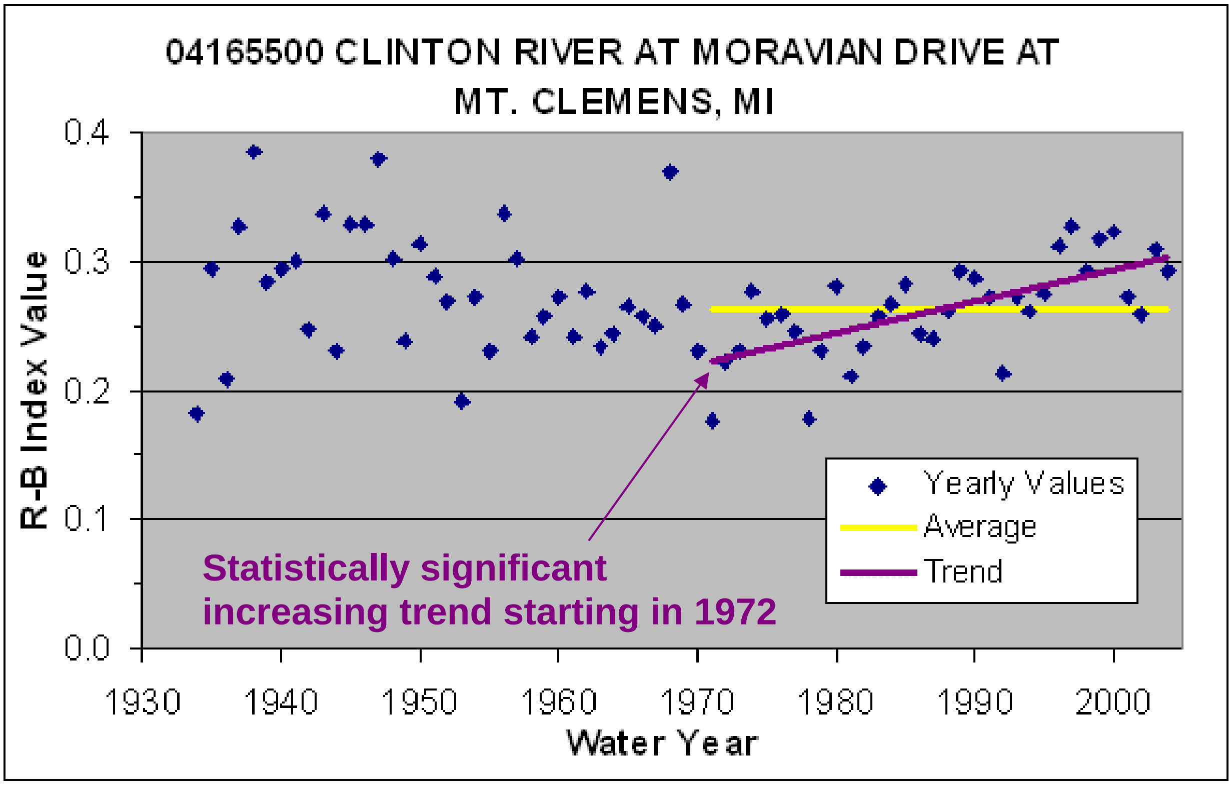

Figure D6 – USGS Gage 04165500 R-B Index Values

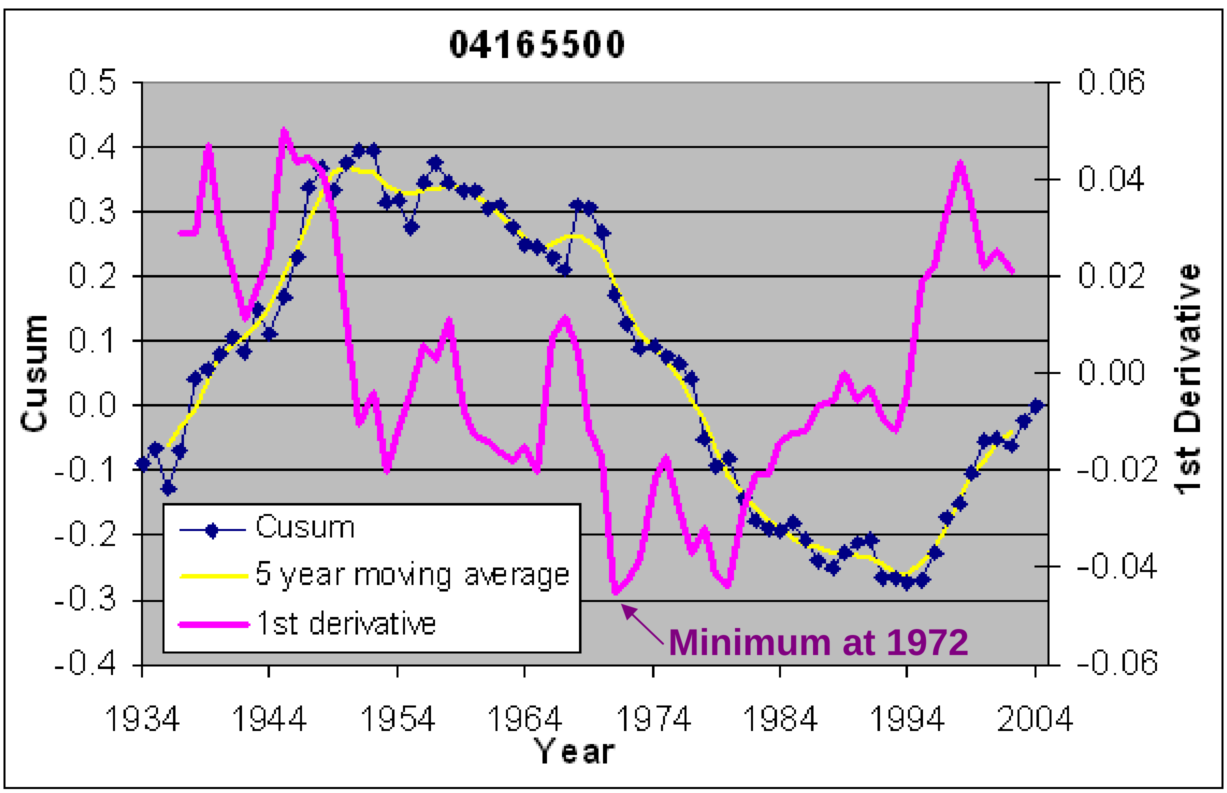

Figure D7 – Cusum analysis, defining potential breakpoint at 1972